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GEOLOGIC OVERVIEW, COAL, AND COALBED METHANE RESOURCES OF RATON MESA REGION, COLORADO AND NEW MEXICO

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1. SUMMARY

The Raton Mesa region occupies approximately 2,200 square miles in southeastern Colorado and northeastern New Mexico. Original in-place coal reserves for minable coalbeds (at least 14 inches thick with less than 3,000 feet of overburden) were estimated by the U.S. Geological Survey to be more than 17 billion tons. More recent geological mapping and new subsurface information show this estimate to be conservative. Test results from the desorption of methane gas from coal cores indicate gas contents ranging from 25 to 490 cubic feet per ton of coal. These test results, used in conjunction with coal resource estimates, indicate that there is at least 8.0 and possibly 18.4 trillion cubic feet of coalbed methane gas present in the Raton Mesa region.

The Raton Mesa region is located in the westernmost part of the Great Plains Province where the Upper Cretacous and Lower Tertiary rocks form a plateau which defines a topographical terrain intermediate between the mountains of Rocky Mountain Province to the west and the lowlands of the Great Plains Province to the east. The region has a semiarid continental climate characterized by light precipitation, low relative humidities, large annual and diurnal temperature ranges, and moderate wind speeds. Regional vegetation varies with elevation, with sagebrush, short grass and cactus prevalent in the lowlands, and pinon, juniper and Ponderosa pine in higher portions of the region.

Three cities--Walsenburg and Trinidad in Colorado, and Raton in New Mexico, located on the eastern margin of the region--and several smaller communities situated on the banks of major rivers comprise the major population centers. Several paved and unimproved roads provide access to the interior of the region. Two freight railroad lines service the region's operating coal mines.

The Raton Mesa region is part of the larger Raton Basin, a north-northwest trending asymmetrical depositional trough formed in Early Pennsylvanian and Permian time. The basin is characterized by a steeply dipping western limb, a gently dipping eastern limb, and a broad, nearly horizontal central portion.

Several thousand feet of Paleozoic and Mesozoic sedimentary rocks are known to be present in the subsurface. Outcrops of these rocks occur west of the region in the foothills of the Sangre de Cristo Mountains. The rocks record several tectonic events that formed uplifted areas to the north, west and south of the basin and supplied enough material to fill the downwarped Raton Basin. In Late Cretaceous time, the area was covered by a major seaway that resulted in the deposition of several hundred feet of transgressive-regressive marine sediments.

The Laramide mountain building orogeny of Late Cretaceous and Early Tertiary time forced the retreat of the sea. The Vermejo and Raton Formations are comprised of the floodplain and swamp deposits that were laid down near the coast of the retreating sea. The coalbeds that were formed in the swamps are lenticular and discontinuous in nature, but include highly accessible reserves that crop out in major river canyons and along the eastern margin of the region.

The coal resources of the region can be summarized as follows:

- The region is divided into three coal fields:
  - The Walsenburg Coal Field lying north of the Huerfano-Las Animas County line in Colorado.
  - The Trinidad Coal Field lying in the central part of the region, north of the Colorado-New Mexico state line and south of the Huerfano-Las Animas County line.
  - The Raton Coal Field lying south of the Colorado-New Mexico state line.
- The coal-bearing units in the region are the Vermejo and Raton Formations.
- Coal rank increases to the south.
  - The Walsenburg Coal Field at the north end of the basin yields steam quality coal.
  - The Trinidad and Raton Coal Fields generally yield high-volatile B to A bituminous coal of coking quality.
- Many of the coalbeds in the region have been intruded and partially destroyed by igneous dikes and sills.
- In the Raton Coal Field there are three significant coalbeds in the Vermejo Formation and seven in the Raton Formation.

- The important coalbeds in the Vermejo Formation are: the Raton, Vermejo, and Sugarite. The Raton coalbed is the most extensive coalbed of the Raton Coal Field.

- In the Raton Formation the main beds are: the Potato Canyon, Tin Pan, Yankee, Left Fork, Cottonwood Canyon, Ancho Canyon, Chimney Canyon, and York Canyon. The York Canyon and Potato Canyon coalbeds are the only coalbeds currently being mined in the Raton Coal Field.

● In the Trinidad and Walsenburg Coal Fields the coalbeds are discontinuous. Because of this problem, the coalbeds have been grouped into coal zones.

  - There are seven zones in the Vermejo Formation. Important coalbeds in this formation include the Cameron, Lower Bunker Hill, Lower Piedmont, Berwind, Lenox, Morley, Piedmont, Pryor, Empire, Majestic, Rapson, Cokedale, and Apache.

  - There are five coal zones in the Raton Formation. Important coalbeds in this formation are: the Frederick, Lower Rugby, Bear Canyon, Martinez, Primrose, Delagua, Primero, Boncarbo, Allen and Ciruela.

Two underground coal mines are presently active in the Raton Coal Field. The York Canyon coalbed, 4 to 10 feet of bituminous coal, is being mined by both underground and stripping methods in the York Canyon. The York Canyon Mine is owned by the Kaiser Steel Corporation. The coal, after extraction, is sized, washed, and shipped by rail to Fontana, California, where it is used in a Kaiser steel mill. Combined production from underground and stripping operations is approximately 1 million tons per year, with an expected annual production rate of 1.5 million tons in the near future. The Potato Canyon coal bed is mined by Kaiser Steel Corporation at an experimental underground mine in Potato Canyon. The purpose of the venture is to test roof conditions in this coalbed.

In the Trinidad Coal Field, the Allen coal mine, located near Stonewall, Colorado is a captured operation owned by C.F.& I. The coalbed being mined is known as the Allen, and is probably correlatable with the Ciruela coalbed. The Allen coalbed averages 5 feet in thickness and is bituminous in rank. The Allen mine eventually will be phased out and replaced by the Maxwell Mine which is located along the Purgatorie River. At the Maxwell Mine, the Apache coalbed, a 3.6 to 5-foot seam of bituminous coal, is being extracted for coking at the Colorado Fuel and Iron Company's steel mill in Pueblo, Colorado. In 1979, the Maxwell Mine had an average daily production of 86,883 tons. The Morley Mine, just north of Raton Pass on I-25, had produced 11 million tons of coal before closing in 1956. It also produced a bituminous coal used by C.F.& I. for coking at its steel mill in Pueblo.

At this writing, no underground coal mines are operating in the Walsenburg Coal Field.

To date, commercially producible quantities of oil and gas have not been identified in the Raton Mesa region. However, drilling density is low, with approximately one well per 20 square miles. Structures tested within the region include the Alamo Dome, the Ojo Anticline, the Morley Dome, and the Tercio Anticline. Wells in each have exhibited shows, but not commercial production rates. Shows of oil and gas have been encountered in fractured Pierre Shale, fractures in an intruded basalt dike in the Pierre Shale, the Trinidad Sandstone and the Vermejo Formation sandstone beds. Limited subsurface data suggest that complex stratigraphic conditions can be expected at depth. It is possible that stratigraphic traps containing oil and/or gas may be encountered.

The Model Dome produced helium from the Permian Lyons Formation. Sheep Mountain contains several shut-in wells capable of producing carbon dioxide gas from the Dakota Sandstone. Gardner, a one-well field, has produced 2,340 barrels of oil and 2,250 MCF of gas in five years of production from the Code11 Sandstone. The Garcia gas field produced 15,561 MCF of gas from the fractured Pierre and Carlile Shales before it was abandoned in the late 1950s; however, that field is currently the target of renewed exploration. All of the above fields lie within the Raton Basin, but none lie within the coal fields of the Raton Mesa region.

Methane drainage has been a problem in underground coal mines of the Raton Mesa region since the first mines opened in 1870. Several disasters have been documented and attributed to the occurrence of methane. Recent estimates of the coalbed methane resource for the Raton Mesa region range from 2 to 4.8 trillion cubic feet of recoverable gas. Tremain (1980) estimated that 311 billion cubic feet of methane is present in a lo-foot thick coalbed underlying an area of 54 square miles in the Trinidad Coal Field. If this estimate is expanded to include most of the region (2,000 square miles), an estimated 8.0 trillion cubic feet of in-place gas is available for production. Danilchik and others (1979) estimated that 84 billion cubic feet of methane is present in a 7-foot coalbed underlying an area of 25 square miles in the Trinidad Coal Field. If this estimate is expanded as above, an estimated 12.0 trillion cubic feet of methane gas is available in the Raton Mesa region. The above two estimates were based on desorption of methane from coal core samples taken in the region. A third estimate was made without methane desorption data. Instead, assumptions were made concerning the amount of methane gas generated during the coalification process and about the degree or level of maturity of the coalbeds in the Raton Mesa region. Using these assumptions for a 15-foot coalbed underlying the Walsenburg and Trinidad Coal Fields, Dolly and Meissner (1977) estimated that 23 trillion cubic feet of methane was generated during coalification. Expanding this estimate to incude the Raton Coal Field and assuming 50 percent retention of the methane in the coalbed, an estimated 18.4 trillion cubic feet of methane gas is available in the Raton Mesa region.

Coalbed methane has been recorded at several drill sites. The Energetics Healy No. 13-8 drill hole showed background gas of 100 percent methane throughout the coal interval. Burnable gas was recovered from the Filon Exploration Corporation's No. 1 Feles Hope drill hole after fracturing a 5-foot Raton Formation coalbed.

The majority of the Raton Mesa region has been designated as a primary target having a high potential for coalbed methane production. It contains significant quantities of high rank bituminous coal within 5,000 feet of the surface. Within the primary target area (Figure 1-1), an area of 310 square miles has been identified as having the greatest potential for the early development of a coalbed methane gas field. Individual site selection should be based on local structure and existing direct indicators of potential coalbed methane. Attractive local structures would be the fold axes and intersections of linear structures. In both cases, stress on the coal-bearing formations should create fractures in which the desorbed methane will collect. Direct indicators of potential coalbed methane include shallow drill holes that flow methane, and methane in the effluent of artesian wells.

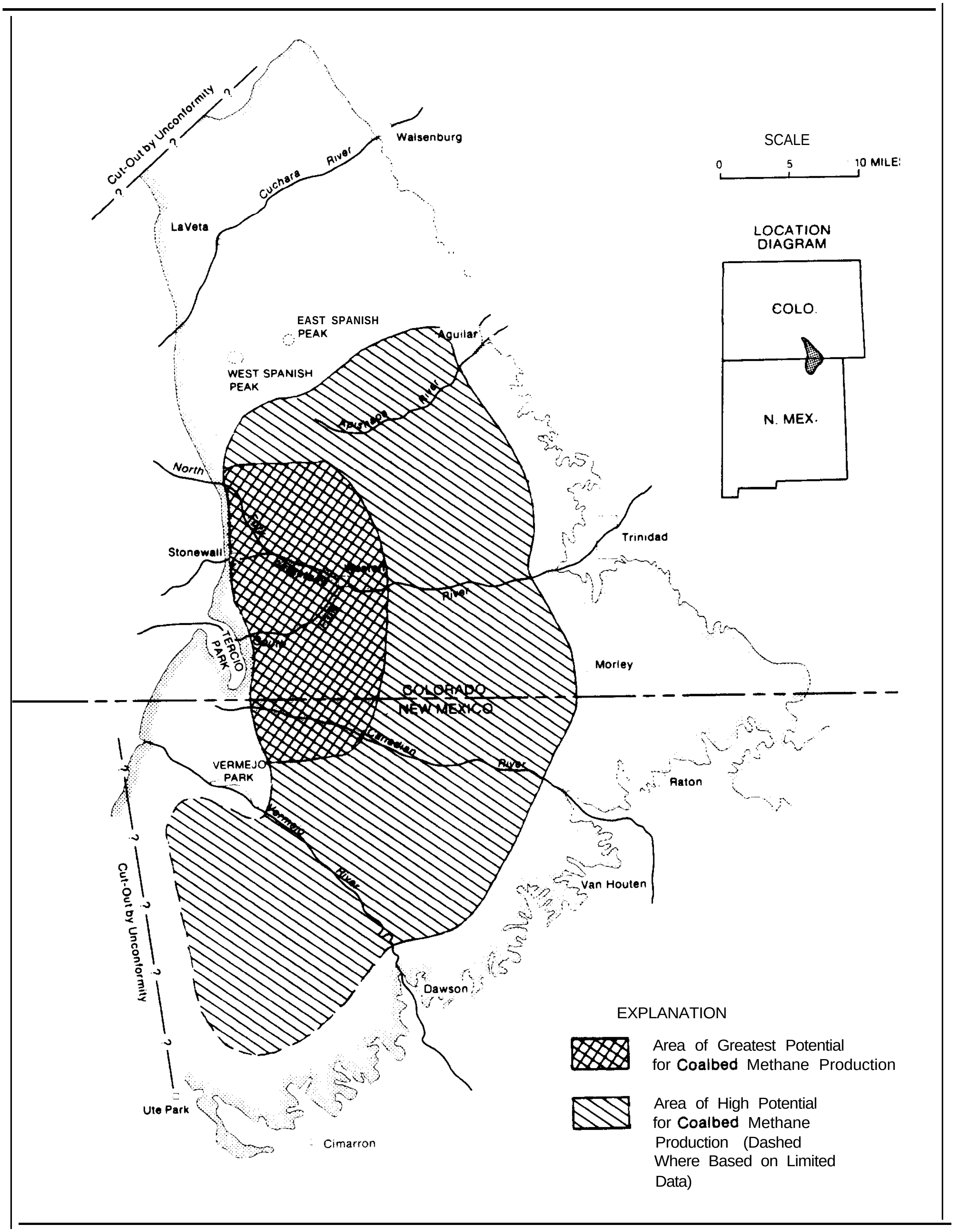


Figure I-l. Redefined Target Area of the Raton Mesa Region

2. INTRODUCTION

This report's objective is twofold: 1) to summarize the general geology and occurrence of coal in the Raton Mesa region of Colorado and New Mexico, and 2) to compile existing information on the occurrence of methane associated with the coalbeds, identify areas of anomalously large amounts of methane, and define a target area for investigating the methane recovery potential. This report was prepared for the U.S. Department of Energy Methane Recovery from Coalbeds Project (MRCP) as part of an effort to define the national coalbed methane resource.

This document is organized into four main parts. General geology of the Raton Mesa region is summarized in Section 3. Younger sedimentary sequences are reported in greater detail as they are the only coal-bearing formations in the region. Principal coal fields and coalbeds are described in Section 4. Whenever possible, references have been included on the extent, thickness, and quality of coal. Section 5 summarizes methane exploration activities and resource estimates. Recommendations for further work are outlined in Section 6. Section 7 lists cited references, and other selected references appear in Section 8. Three appendices are included to facilitate the use of this report. Appendix A contains topographic maps of the Raton Mesa region and topographic map indexes of Colorado and New Mexico. Appendix B contains geologic map indexes of Colorado and New Mexico, and Appendix C contains water-resources investigations indexes of Colorado and New Mexico.

3. BASIN SETTING

3.1 GEOGRAPHY/PHYSIOGRAPHY

The Raton Mesa region occupies approximately 2,200 square miles in southeastern Colorado and northeastern New Mexico (Figure 3-1). The Raton Mesa is defined by the cliff-forming Upper Cretaceous Trinidad Sandstone occurring within Huerfano and Las Animas Counties of Colorado, and Colfax County of New Mexico. The region is 175 miles long from north to south, and 65 miles wide at its maximum near the Colorado-New Mexico state line.

The Raton Mesa region is in the westernmost portion of the Great Plains Province where the coal-bearing Upper Cretaceous and Paleocene formations form an intermediate plateau between the mountains of the Rocky Mountain Province to the west and the lowlands of the Great Plains Province to the east. Erosion has broadly dissected the plateau into a complex system of deep canyons, prominent ridges, and flat-topped mesas. Toward the northern part of the field, the topography gradually changes to rolling hills, diminishing in magnitude until the Raton Mesa region merges with Huerfano Park.

Regional elevations vary from about 6,100 feet along the eastern margin to approximately 10,000 feet above sea level along the southwestern margin. Two conical mountains, East Spanish Peak with an elevation of 12,669 feet, and West Spanish Peak at 13,610 feet, rise abruptly along the northern half of the region, and dominate the surrounding country. The land slopes from the peaks to the north, south, and east in a series of discontinuous steplike platforms. Igneous dikes crisscross the region, and where exposed by erosion stand as vertical walls up to 100 feet high. The eastern edge of the region is characterized by steep escarpments ranging from 500 to more than 2,000 feet high above the surrounding plains.

Climate in the Raton Mesa region, classified as mild arid or semiarid continental, is characterized by light precipitation, low relative humidities, large annual and diurnal temperature ranges, and moderate wind speeds.

The principal moisture sources for precipitation in this region are the Pacific Ocean and the Gulf of Mexico. Mean annual precipitation is approximately 20 inches, with 70 to 80 percent falling from April through September. Average annual precipitation for the region is given in Figure 3-2. Summer precipitation is primarily from short, intense thunderstorms that produce rain and occasionally hail. Mean maximum July temperature averages 90°F.

Winter is the driest season of the year because the storms, coming predominantly from the north, carry little moisture. Storm frequency generally increases in the fall and winter, and decreases in the spring. Such winter storms bring polar air masses that cause falling temperatures. When these storms from the north mix with moist air from the south, heavy snowfalls produce blizzard conditions. Mean minimum January temperature varies from 0°F to 10°F. Occasionally, during winter, when the plains are blanketed by a shallow layer of cold air, strong westerly winds work their way down to the surface. Warmed by rapid descent, these winds bring a large and sudden temperature increase. Known as the chinook, this phenomenon can cause a 25°F increase in temperature in a relatively short time.

The freeze-free season in this region is approximately 140 days. Both irrigation and dry farming techniques are practiced here, and garden vegetables, melons, sugar beets, alfalfa, wheat, corn, and brown corn are the principal crops. Erratic variation in precipitation and occasional hailstorms affect the production potential. Periodic droughts, lasting one or two years, also cause serious agricultural and economic problems. Livestock raising is the most extensive agricultural pursuit, with over 40 percent of the region used as pasture land. Other land uses include mining, lumbering, and gas and oil production.

Short grass, sagebrush, and many varieties of cactus are common at lower altitudes. At higher elevations the land supports growths of piñon, juniper, sagebrush, and scrub oak. The highest areas below timberline are covered by ponderosa pine whereas the stream valleys support growths of cottonwood trees.

3.2 CULTURAL FEATURES

Interstate 25 and U.S. Highway 85 are the primary access roads to the Raton Mesa region, trending north-south along the region's eastern margin. Two Colorado state highways, 111 and 12, provide access to the Raton Mesa interior. Highway 111 trends northeast-southwest and passes through the cities of Walsenburg and La Veta, Colorado. Highway 12 passes east-west through the center of the region, and U.S. Highway 64 skirts its southern boundary. Additional state highways, along with numerous unimproved roads, provide access to the northern, eastern, and southwestern portions of the region (Figure 3-l).

Populations of the major cities have been steadily declining since the 1930s, primarily because of the decline in mining activity. Trinidad, Colorado (population 9,901, 1970 census), the region's largest population center, has shown approximately 20 percent decrease in population over the past 20 years. The same is true for Walsenburg, Colorado (population 4,329, 1970 census, down 23 percent), and Raton, New Mexico (population 6,962, 1970 census, down 18 percent). The rural population is centered mainly on small ranching and farming communities along the Purgatoire, Cuchara, Apishapa, Canadian, and Vermejo Rivers.

Several major railroads service regional population centers. The Denver and Rio Grande Western runs east-west through Walsenburg, La Veta, and Alamosa. The Colorado and Southern Railroad services Walsenburg and Trinidad. The Atchison, Topeka and Santa Fe main line passes through Trinidad, over Raton Pass, and through Raton. Freight rail lines extend into the coal fields from population centers along the margins of the region. The Atchinson, Topeka and Santa Fe has two freight lines: one runs north and west from French, New Mexico, and follows the Vermejo River to the York Canyon Mine; the second originates in Raton and runs northwest to a site near Blossburg, New Mexico. The Colorado and Wyoming Railroad freight line runs west from Trinidad to the Allen Mine near Stonewall, Colorado, and the Denver and Rio Grande Western spur runs north from Walsenburg to the site of Tioga, Colorado.

One industrial gas pipeline serves population centers on the eastern margin of the Raton Mesa region (Figure 3-3). The northern half of the pipeline runs from Trinidad to Walsenburg, the southern half from Trinidad through Raton and Springer, New Mexico to Las Vegas, New Mexico (National Atlas, 1977).

3.3 GEOLOGY

3.3.1 Structure

The Raton Mesa region is situated in the northern half of the Raton Basin, southernmost of the Laramide basins along the eastern margin of the Rocky Mountains. The Raton Basin is bordered on the west by the Sangre de Cristo Uplift and merges to the east with the Sierra Grande-Las Animas Arch. The Wet Mountains Uplift and its southeastern continuation, the Apishapa Arch, make up the northern boundary (Figure 3-4).

Structural elements of the Raton Basin were formed mainly during Early Pennsylvanian and Permian time (Blatz, 1965). During that time several thousand feet of sediments were deposited in the Central Colorado Basin, a geosynclinal structure that trended northwestward between the ancestral Wet Mountains and the Apishapa Uplift on the east, and the San Luis Uplift on the west (Figure 3-5). The Central Colorado Basin probably was connected to the Rowe-Mora Basin to the south, but during Middle and Late Pennsylvaniantime the ancestral Cimarron Arch rose as part of the Sierra Grande Uplift and partially separated the two basins (Blatz, 1965).

The Raton Basin is internally divided by the east-west trending Cimarron Arch, named for the Cimarron River, which lies on or near the arch between Ute Park and Springer, New Mexico. The Las Vegas Sub-basin lies to the south of the Cimarron Arch and is not discussed in detail in this report.

The Raton Basin is an asymmetrical trough that trends north in New Mexico and north-northwest in Colorado. It is characterized by a steep western limb, a gently sloping eastern limb, and a broad central portion in which the beds are essentially horizontal (Figure 3-6). The beds at the western edge of the coal region dip steeply to the east, and are vertical to overturned in places. Toward the axis of the basin, the dip of the beds gradually decreases. The eastern limb of the trough has a gentle dip of 1° to 10" to the west (Figure 3-7). The Colorado portion of the basin is known as the La Veta Syncline (Johnson and Stephens, 1954). In the northernmost part of the Raton Mesa region, the Greenhorn Anticline plunges southward from the Wet Mountains and splits the La Veta Syncline into a major syncline to the west (La Veta), and a minor one, the Delcarbon Syncline (Johnson and Stephens, 1954) to the east (Figure 3-8).

One of the most prominent structural features in the Raton Mesa region is the Vermejo Park Anticline (Figure 3-8). This feature exhibits more than 2,500 feet of structural relief across a distance of four miles on its east flank, and has more than 500 feet of closure (Pillmore, 1969). Drilling records from the Union Oil Company's Bartlett Numbers 1 and 2 drillholes indicate that the folding was caused by underlying intrusives (Pillmore, 1969).

Middle Tertiary intrusive activity related to the Spanish Peak's stocks and the associated radial dike and sill complexes appears to be concordant with the regional structure of associated sedimentary beds. It is possible that one or more of the anticlinal structures is a laccolith or a dome formed over an underlying stock.

Other intrusive related structural features in the Raton Mesa area include the Alamo Dome in Section 34, T27S, R68W. This closed domal feature occurs along the plunge of the Greenhorn Anticline. Tertiary igneous rocks exposed nearby indicate that this feature may be associated with an intrusive body. The Ojo structure in Sections 3 and 4, T29S, R69W is a tight anticlinal feature complicated by faulting. The Terico Anticline in the southwest quarter of T34S, R68W on the west limb of the basin is a large breached anticlinal fold outlined by surface outcrops and dip patterns. The Morley Dome in Section 36, T34S, R64W, is a small anticline which, in places, has been eroded down to the Pierre Shale.

The flanks of the Raton Basin are characterized by uniform dips and a relatively simple structure, however, several faults and folds complicate the structural trends of the region. A narrow, northeasterly trending monocline is located 3 miles northwest of Aquilar, Colorado. The beds on the northeast side of the monocline are downfolded through a zone less than one-fourth of a mile wide and have dips that may be as great as 50" in places. The vertical displacement is southwestward with a maximum of nearly 200 feet. The fold is sharp, and at places the dip increases from 2" to greater than 40" within a horizontal distance of less than 400 feet (Harbor and Dixon, 1959). Several long, narrow, irregular folds of low structural relief occur south of the Spanish Peaks. These folds, which have no preferred orientation, appear to have been formed at the same time as the basin (Johnson, 1961).

Faulting, although rare, is present in the region. In the western margin of the basin, one to three thrust faults parallel the east front of the Sangre de Cristo Mountains. One thrust sheet is complicated by a series of overturned structures that apparently resulted from compression associated with the thrusting.

Isolated groups of normal faults are found in the region. Several small normal faults occur northeast of Weston, Colorado. These faults trend north, east, northeast, and northwest, and seem to be related to a small anticline or dome. Most of the faults near Weston have a displacement of less than 50 feet. Two small normal faults at the north end of the Walsenburg coal field cut the two flanks of the Delcarbon Syncline. These faults trend generally parallel to the axis of the syncline with the upthrown sides toward the axis of the syncline. The displacement of both faults is less than 50 feet (Johnson, 1961).

The sedimentary rocks between the Spanish Peaks appear to have been brought from depth by the intrusion of the East Spanish Peak magma. The faults associated with this intrusion are normal with a vertical displacement of 6,000 feet (Johnson, 1961). On the western margin of the basin, Wanek (1963) mapped several en echelon faults that displace the Poison Canyon Formation approximately 1,500 feet.

3.3.2 Stratigraphy

During Precambrian time several thousand feet of sediments were deposited in the Raton Mesa region. These sediments were subsequently deformed, intruded by several igneous bodies, and metamorphosed into gneiss, quartzite and schist. Later, these rocks were subjected to an extended period of erosion, lasting perhaps until Late Mississippian time in sane areas of the region.

During much of Paleozoic time, the Raton Basin probably was part of a broad, southwest trending, shelf-like "continental backbone" (King, 1951) on which sedimentary rocks older than Devonian are not present. It is not presently known whether or not pre-Devonian sediments were deposited and subsequently eroded away to the Precambrian crystalline basement. Maher and Collins (1949) suggested that the thick sequences of Paleozoic rocks of Kansas, Oklahoma, and eastern Colorado which thin toward the Sierra Grande Uplift indicate that it had a long history as a positive (nondepositional) area.

The oldest sedimentary rocks present in the Raton Basin are marine sandstone and dolanitic limestone of the Espiritu Santo Formation of Devonian (?) age (Figure 3-9). This unit ranges from a few feet to 80 feet in thickness. The Tererro Formation of Mississippian age rests unconformably on the Espiritu Santo Formation. This unit is composed of limestone breccia and marine conglanerate, clastic and crystalline limestone, and siltstone varying in thickness from a few feet to more than 100 feet.

The Magdalena Group of Pennsylvanian age, and the Sangre de Cristo Formation of Pennsylvanian and Permian age, record the first stages of the formation of the Raton Basin when the orogenic forces that produced the Ancestral Rockies began to downwarp the Central Colorado and Rowe-Mora Basins. These complex suites of sedimentary rocks, whose vertical and lateral variations reflect several stages of formation and eventual filling of the geosynclinal basin, have an cumulative thickness in excess of 10,000 feet (Blatz, 1965).

The Lower Pennsylvanian sediments, the Magdelena Group, consist of the Sandia Formation and the overlying Madera Limestone. The Sandia Formation is a mixture of coarse-grained conglomeratic sandstone, dark-gray shale, and thin limestone beds deposited in a mixed terrestrial environment during a general transgression of the Pennsylvanian sea. The Madera Limestone consists of interbedded crystalline fossiliferous limestone, dark gray, green and red shales, and arkosic sandstone. The Madera Limestone ranges from 4,000 to 5,000 feet thick. The lower beds were deposited in a primarily marine environment; whereas the upper beds were deposited in a mixed marine-terrestrial environment that recorded a period of accelerated tectonic activity in the geosynclinal area and the San Luis, Wet Mountains-Apishapa, and Sierra Grande Uplifts. The Magdelena Group wedges out in the eastern part of the Raton Basin (Figure 3-10).

The Sangre de Cristo Formation (Hills, 1899) of Pennsylvanian and Permian age is composed primarily of thick red and green shales with interbedded arkose, conglomerates, and a few beds of thin limestone. Most of these rocks represent a nonmarine depositional environment, but the lower third contains a few thin beds of marine limestone (Zeller and Blatz, 1954). The source of the arkosic material was the San Luis Uplift to the west, and the Wet Mountains-Apishapa and Sierra Grande Uplifts to the east. These uplifted areas supplied an estimated 6,500 to 9,500 feet of sediments to the western part of the Raton Basin. This was enough to fill up the basin, force the sea out, and cause the deposits to lap up onto Precambrian rock on the eastern uplift. The tectonic elements established during the late Paleozoic set the stage for later depositional environments and geologic structure.

In the waning phase of the Pennsylvanian-Permian orogeny, the sea returned to cover the Raton Basin, and several hundred feet of sediments were deposited. In the Raton Basin these sediments are referred to as the Lykins Formation and an unnamed unit. These deposits wedge out to the west and are not present at outcrops on the edge of the Wet Mountains Uplift. Uninterrupted deposition continued through all of Permian time. The marine sediments grade laterally into terrestrial facies on the flanks of the uplifts to the east and west. To the south, in the Las Vegas Sub-basin, lithologically dissimilar rocks occupying the same stratigraphic interval are the Yeso Formation, Glorieta Sandstone, San Andres Limestone, and the Bernal Formation (Figure 3-11).

Following an extended period of nondeposition and minor amounts of erosion, terrestrial rocks of Late Triassic age were deposited as fluvial sandstones and shales over much of the Raton Basin region. These sediments, known as the Dockum Group, are approximately 300 to 400 feet thick on the eastern limb of the basin and thin northward and westward, eventually wedging out in the subsurface. These sediments were derived in part from underlying Permian rocks. The principal source of material was the San Luis Uplift and probably the ancestral Wet Mountains Uplift.

In Late Jurassic time an extensive series of shallow marine and terrestrial deposits were laid down over the entire Raton Basin. These beds range in thickness from about 100 to 600 feet; the variations in thickness are attributed to an erosion surface at the top of the Jurassic rocks.

The Ocate Sandstone is the basal Jurassic unit which lies unconformably on the Sangre de Cristo Formation and younger Permian rocks. This unit correlates with the Entrada Sandstone of Utah (Johnson, 1959), and the Wingate Sandstone of western Colorado. The Ocate thins northward and is absent from the eastern flank of the Wet Mountains Uplift. The Ocate probably was deposited on or near beaches, and near-shore marine environments during the transgression of a shallow sea. This sandstone is conformably overlain by the Wanakah Formation which consists of interbedded gray shale, fine-grained sandstone, siltstone, and thin beds of light red sandstone and shale. The Wanakah Formation is in turn conformably overlain by the Morrison Formation. The Morrison Formation varies considerably in thickness because of regional warping, gentle local folding, and erosion of the upper beds prior to deposition of the overlying Purgatoire Formation. The Morrison Formation is generally thicker in the western parts of the Raton Basin and thins irregularly eastward into the Sierra Grande and Apishapa Arches and the Wet Mountains Uplift. This suite of fluvial deposits consists primarily of red, gray and green shale, and thin local limestone beds. The source area for the Morrison Formation, as well as the other Jurassic rocks, was south of the Raton Basin in the central New Mexico highland. This is evident by the facies changes and southward thickening of sandstone units in the southern portion of the basin, and in east-central and west-central New Mexico.

The Purgatoire Formation of Early Cretaceous age rests unconformably on the Morrison Formation, and is present in most of the Raton Basin and the Sierra Grande and Apishapa Arches. The Purgatoire Formation consists of a lower conglaneratic sandstone member, and an upper member composed of gray carbonaceous to coaly shale and interbedded thin sandstone 100 to 150 feet thick.

The Dakota Sandstone Group lies conformably on the Purgatoire Formation. The Dakota Sandstone Group is generally about 100 feet thick over much of the Raton Basin and consists of several thin to thick even-bedded sandstones interbedded with thin gray shales. In general, the sandstone beds thin eastward and the proportion of shale increases slightly eastward. The Dakota Sandstone Group represents the initial dune-beach-shallow marine and transgressional phases of the Greenhorn marine cycle (Figure 3-12) (Kauffman, et al, 1969).

The rest of the Greenhorn marine cycle is recorded in the members of the Benton Formation, which includes the Graneros Shale, the Greenhorn Limestone, and the Carlile Shale up through the Code11 Sandstone (Figure 3-13). A second half-cycle, the transgression of the Niobrara cycle, is recorded in the overlying Juana Lopez Member of the Carlile Shale through the Fort Hayes Limestone of the Niobrara Formation. These cycles, like all others in the Western Interior Basin of the United States, are characterized by the repetition of 12 major lithofacies during one transgressive or regressive half-cycle. The principal lithofacies used by Kauffman (1967) to model the Western Interior Cretaceres cycles are sequentially represented in the Greenhorn and Niobrara cycles. The lithofacies used by Kauffman are described below in ascending order during transgression (order reversed during regression).

1. Coastal plain fluvial, marsh, and estuarine sediments; highly carbonaceous or variegated clays and silts, lenticular sandstones (locally the top of the Code11 Sandstone).

2. Massive sandstones of the strand-dune-beach-bar-marine delta complex (main sandstones of the Code11 Sandstone).

3. Slabby thin-bedded and shaly sandstone, and siltstone beds of shallow sublittoral origin (lower member of the Graneros Shale, lower Code11 Sandstone transition Unit).

4a. Nearshore calcarenites of beach and shallow sublittoral origin (local calcarenites of lower shale members, Graneros Shale; Juana Lopez Member; local base of upper shale member, Carlile Shale).

4b. Clean calcarenite of outer shelf origin, probably formed in relatively shallow, agitated waters.

5. Silty to sandy dark clay shale of shallow to moderate depth, inner sublittoral origin (lower shale member, Graneros Shale, lower calcisiltic part of upper shale member, Carlile Shale).

6. Dark noncalcareous shale of midshelf, quiet water origin (upper shale member, Graneros Shale; middle part of upper shale member, Carlile Shale).

7. Dark, calcareous clay shale of quiet water, midshelf origin (upper few feet of Graneros Shale, middle of upper shale member of Carlile Shale).

8. Chalky to highly calcareous, light colored clay shale of quiet water, outer shelf origin (upper part of upper shale member, Carlile Shale).

9. Interbedded shaly chalks, chalky shales, and thin limestones of quiet water, outer shelf origin (locally the upper few feet of the upper shale member, Carlile Shale).

10. Sandy or calcarenitic massive limestone of outer shelf origin, formed in relatively quiet waters with some current agitation (lower beds of the Fort Hays Limestone).

11. Massive, very fine-grained limestone or calcilutite of quiet water, outer shelf origin (most limestone units of the western facies of the Fort Hays Limestone).

12. Massive foraminiferal chalk and chalky limestone of quiet water, outer shelf origin (scattered limestone units of the Fort Hays Limestone Members, western facies; most limestones of the Fort Hays).

The cumulative thickness of these sediments in the Raton Basin ranges from 500 to approximately 800 feet.

The Smokey Hill Marl Member of the Niobrara Formation lies conformably on top of the Fort Hays Limestone. This unit, approximately 600 feet thick, is composed of marly shale with interbedded thin limestone and sandy shale. The Smokey Hill Marl Member and the Pierre Shale were deposited during Lower and Middle Cretaceous time, when the area presently occupied by the Raton Basin was part of a large interior seaway that extended from northwest Canada to the Gulf of Mexico (Gill and Coban, 1966). This seaway was dominated by shallow marine shelf environments with water depths generally less than 300 feet and rarely over 500 feet. The Pierre Shale, composed of shaley sandstone interbedded with gray to black silty shale, is approximately 1,500 to 2,500 feet thick in the Raton Basin. The easily weathered shale forms valleys and lowlands around the coal region.

The youngest beds of the Pierre Shale record the beginning of the retreat of the marine sea and the rise of the Laramide Rocky Mountains. As the sea retreated from the basin, the sediments of the Pierre Shale became less clayey and more sandy. The Pierre Shale locally intertongues with the overlying Trinidad Sandstone through a transition zone 20 to 50 feet thick (Johnson and Wood, 1956) and represents the epeirogenic movement west of the basin. The resulting uplift forced the strand line to retreat to the northeast. As the strand line retreated, the Trinidad Sandstone accumulated in the sea and on its margins as regressive beach and offshore deposits. The Trinidad Sandstone is thickest near the axis of the Raton Basin where it ranges from 140 feet to about 300 feet thick. More recent work (Billingsley, 1977; Manzolillo, 1976) divide the sandstone into an upper fluvial zone and a lower delta front sandstone. The lower Trinidad, according to Billingsley (1977) and Manzolillo (1976), usually exhibits tabular bedding, ball-and-pillow structure, and littoral to shallow neritic fossils such as Halymenites and Ophimorpha. The upper Trinidad is a buff to light gray fining upward, medium- to fine-grained sandstone. Billingsley (1977) and Manzolillo (1976) interpret it as a salt marsh estuarine or distributary channel facies. The lower Trinidad is a buff to gray, very fine to fine-grained quartz sandstone that increases in grain size upward. Outcrops of the Trinidad Sandstone characteristically occur as one or two steep ledges or as a single massive cliff which separates the coal basin from the plains. It also outcrops in the region adjacent to the Sangre de Cristo Mountain Front along the west side of the coal field. Here it occurs as a near vertical hogback, often standing over 150 feet above the surrounding landscape (Figure 3-6). The Trinidad is believed to be a slightly younger representative of the same littoral-paralic regressive sequence represented by the gas-productive Pictured Cliffs Sandstone of the San Juan Basin (Weimer, 1960) (Figure 3-14).

The Trinidad Sandstone is overlain by and intertongues with the Upper Cretaceous Vetmejo Formation (Lee, 1913) (Figure 3-15). The contact of the Vermejo with the underlying Trinidad Sandstone is generally taken at the base of the lowest coalbed, carbonaceous shale, or claystone in the Vermejo. The contact with the overlying Raton Formation is generally taken at the bottom of either the "basal Raton Conglomerate" or the first massive channel sand. Partial time equivalency of the Vermejo with both underlying and overlying units is indicated by intertonguing of the basal Vermejo with Trinidad Sandstone toward the northeast and with the Raton Formation to the southwest (Wood, et al, 1957). The Vermejo Formation is composed of up to 550 feet of varied proportions of buff to gray shale, carbonaceous shale, coal, and slightly arkosic fine- to medium-grained sandstones that were deposited in swamps and on floodplains near the coast of the retreating sea. The Vermejo is believed to be the slightly younger equivalent of an identical lithofacies unit represented by the coal-bearing Fruitland Formation of the San Juan Basin (Figure 3-14).

Coalbeds in the Vermejo Formation range from a few inches to several feet in thickness, and are present throughout most of the Raton Mesa region. The most persistent and widely mined bed in the Raton Coal Field is the Raton Coalbed that normally is found within a few feet of the base of the Vermejo Formation. Near the top of the Vermejo Formation is the Vermejo Coalbed. The Vermejo Coalbed appears to be restricted to the western part of the region where the formation is more than 250 feet thick (Pillmore, 1969b).

The Raton Formation, as named by Hayden (1869) and restricted by Lee (1917), is the thickest and most widely distributed of the coal-bearing units in the region. The Raton Formation, as well as the Vermejo Formation, Trinidad Sandstone, and Pierre Shale, is truncated by the erosional surface at the base of the Poison Canyon Formation. The contact between the Raton and the Poison Canyon Formations is generally indefinite and gradational through a transition zone up to 150 feet thick (Figure 3-16). The contact is mapped between the highest coal or carbonaceous zone, and at the bottom of a sandstone unit that contains a basal conglomerate zone.

The Raton Formation is comprised of three generally recognizable field divisions: a basal sandstone which is conglomeratic throughout most of the western part of the field; a lower zone which is predominantly sandstone and mudstone; and an upper coal-bearing zone, consisting of sandstone, siltstone, mudstone, and beds of coal. These zones vary greatly in lithology and thickness throughout the basin. Total thickness of the Raton Formation ranges from 0 to 1,700 feet. The thickest coal-bearing zone of the Raton Formation ranges from 0 feet in the western part of the basin to over 1,000 feet in the central part. All commercial coalbeds in the Raton Formation occur in this zone (Lee, 1917).

The Raton Formation is of Upper Cretaceous-Lower Tertiary (Paleocene) age and contains the Mesozoic-Cenezoic time boundary. The basal conglomerate of the Raton Formation records the beginning of the Laramide orogenic event. The lithology of the rapidly deposited basal conglomerate indicates Precambrian terrains north and west of the basin as the source areas of the sediment. Depositional conditions remained similar to that of the Vermejo Formation; subsequent sediments of the Raton Formation accumulated on flood plains and in swamps at the same time that the Poison Canyon Formation sediments were deposited on piedmont surfaces farther west. Intermittent minor tectonic disturbances continued in the uplifted areas west and north of the basin.

The Poison Canyon Formation of Paleocene age ranges from 0 to 2,500 feet thick (Hills, 1888). It consists of massive, lenticular, coarse-grained to conglomeratic, arkosic sandstone and thin, yellow shale derived mainly from Precambrian terrains to the west. Locally, thin, irregular, impure coalbeds occur near the base of the Poison Canyon Formation. During middle Paleocene, while the Upper Poison Canyon Formation was deposited in the southern part of the basin, the northwestern part of the basin was uplifted and older formations were tilted, folded, and eroded. The Lower Poison Canyon to the Upper Niobrara Formations was beveled to a local base level during this period (Figure 3-17).

Sediments derived from this erosion cycle were deposited in the rest of the basin as layers of pebbles, cobbles, and coarse sand, and formed the uppermost beds of the Poison Canyon Formations. In late Paleocene or early Eocene the mountains to the west and north were again uplifted and the Raton Mesa region was tilted and folded. The Poison Canyon Formation was eroded from the uplifted areas to the west and north of the Raton Basin, and sediments of the Cuchara Formations (Hills, 1891) of Eocene age were deposited on piedmonts and flood plains in the northern part of the Raton Mesa region. These sediments are composed of thin to thick beds of red, pink and white sandstone, and thin beds of red and tan shale and measure 0 to 5,000 feet in thickness.

The late Eocene Huerfano Formation rests on the Cuchara Formation (Hills, 1888). The Huerfano Formation appears to lie conformably on the Cuchara Formation on the north and east flanks of West Spanish Peak, but unconformably on the south and west flanks of the peak (Johnson, 1961). The Huerfano Formation consists of interbedded arkose and graywacke conglomerate, conglomeratic sandstone, and siltstone with a few beds of claystone. The formation becomes more conglomeratic upward; the top of the formation contains boulders up to 10 feet in diameter. These sediments were deposited as the result of another episode of uplifting in the regions west and north of the Raton Basin.

In late Eocene or early Oligocene time, extensive major thrusting, normal faulting, and folding occurred throughout the present mountainous areas of southeastern Colorado and northeastern New Mexico and resulted in formation of the present day Sangre de Cristo Mountains, Wet Mountains and Raton Basin. During this last pulse of the Laramide orogeny, the sedimentary rocks of the Raton Basin were intruded by numerous sills, dikes, plugs, stocks, laccoliths, and sole injections of basic to silicic igneous rocks.

Volcanic stocks, which form the present-day Spanish Peaks, were emplaced near the deepest part of the Raton Basin during this time. Related sills and plugs are widespread. These intrusions had an intense metamorphic effect that was limited to relatively minor contact zones immediately adjacent to the intrusives. Regional low-level metamorphism is believed responsible for the anomalously high rank of coals found in the basin (Dolly and Meissner, 1977). Today, the Raton Mesa region is an area of anomalously high terrestrial heat flow (Figure 3-18). This "hot spot" is probably due to the intrusion of the more deeply-seated igneous rocks.

The dikes of the Raton Basin range from basic to silicic in composition. Most of the dikes in the region are vertical or near-vertical and range in thickness from a few inches to more than 100 feet. Most of the dikes belong to two systems. The first system radiates from the Spanish Peaks area, and, along with some of the sills and small plugs, appears to be related to intrusive bodies that form the Spanish Peaks. The second, more extensive, system of dikes consists of subparallel dikes that are present throughout the entire region. The strike of this system is from N 60°E in the northern part of the region to N 86°E in the southern part. The dikes trend perpendicular to the axis of Raton Basin, and were probably intruded along fractures resulting from tension during the folding of the basin. Other small localized swarms of dikes are present throughout the region (Johnson, 1958, 1961). Figure 3-19 illustrates the extent to which coalbeds have been altered or destroyed by igneous intrusions in the Raton Mesa region.

After the last period of tectonic activity, the uplifted areas were then subjected to a period of intense erosion. The only area where a record of this erosion is preserved is north and west of the basin in Huerfano Park, a northern extension of the Raton Basin. Here, the Oligocene Farisita Conglomerate and Miocene Devil's Hole Formation composed of 25 to 2,500 feet of pebbles, cobbles, boulders, sandstone, water laid tuff and volcanic conglomerate rests unconformably on rocks dating from Precambrian to Oligocene.

During Quaternary time, volcanoes in the east and southern parts of Raton Basin extruded basaltic lava over large areas of the basin. Remnants of these flows are preserved on high mesas north and east of the city of Raton (Johnson, 1959). Also during this time, sills were extruded extensively into and along coalbeds, especially into the Vermejo Formation. The intrusions usually altered or completely assimilated and destroyed the coal (Figure 3-19). Locally, prismatic coke was formed by the sills; and near Raton, potentially commercial graphite was formed by metamorphism of the Raton Coalbed in the Vermejo Formation during intrusion (Lee, 1917). Erosion has continued uninterrupted since the last volcanic episode, and, as a result, only small remnants of the younger Cenozoic formations are preserved.

Quaternary alluvium deposits are found throughout the basin. Gravel and sand deposits, up to 30 feet in thickness, are present along many of the major present-day stream channels such as the Purgatoire and Vermejo Rivers. Landslide debris and talus cover many of the mountain slopes, and alluvial fans are found along the base of many mountains. Coarse morainal deposits are present at the lower termination of the Cirque Basin on the north side of West Spanish Peak (Johnson, 1961). Soil and pediment deposits cover much of the basin. Quaternary deposits generally are poorly sorted and unconsolidated.

3.3.3 Basin Hydrology

3.3.3.1 Surface

The Raton Mesa region comprises the westernmost part of the Arkansas River Basin which makes up the northwestern portion of the Lower Mississippi River Basin. The Raton Mesa region has a dendritic drainage pattern. It is drained by several predominantly easterly flowing streams and rivers. Evapotranspiration potential in the region is very high and many streams are intermittent in nature and flow only as a response to recent precipitation. Table 3-l is a summary of the runoff characteristics of the major rivers in the Raton Mesa region.

Several towns along the eastern boundary of the region use surface runoff or stream flow as a municipal water source. Raton's principal water supply is Lake Malloya, an artifical lake 7 miles northeast of the city, on the headwaters of Chicorito Creek. Springs issuing from the base of the basalt-capped mesas surrounding the lake constitute a year-round supply of high quality water. The springs, recharged by precipitation on the mesas, have flows of less than 50 gallons per minute (gpm).

The city of Trinidad also collects and stores surface runoff as a municipal water supply. Most of the smaller communities either divert and store surface runoff, or dig large rectangular wells in the alluvium and pediment gravels that occur as a thin veneer over most of the region.

3.3.3.2 Subsurface

Very little is known about the water resources of the deeper formations in the region. This is due primarily to the low level of industrialization. Most of the water wells in the region are producing from shallow alluvial gravels less than 50 feet thick. In a few places, cisterns are used to store rain water.

Potential deep aquifers include:

1) Pre-Dakota rocks, including the Dockum group, the Ocate Sandstone, and the Morrison Formation, are probably of minimal economic value as they are within drilling depth in limited areas. The Ocate Sandstone has good permeability, as do the poorly cemented sandstone beds of the Morrison Formation, and probably would be of significant value if located at shallower depths. The recharge area for these formations is west of the basin in the Vermejo Park Anticline.

2) The Dakota Sandstone probably is saturated with water confined under artesian pressure by the overlying Graneros Shale over most of the region. The recharge area for this aquifer is in the

vicinity of Vermejo Park, and west of the region where the unit crops out as a narrow band. Several seeps and wells are located southeast of the region where well measurement indicates water movement to the southeast and south. Transmissibility is low because of the tightly cemented character of the sandstone. A study of the outcrops of the lower part of the aquifer suggests that it is somewhat more permeable than the upper part. East of the basin, quality of the water from this aquifer is usually poor. Locally, at depth, it tends to be high in sodium chloride, sodium bicarbonate, and fluoride. Reasons for the poor water quality are not positively known. Griggs (1948) postulated that its poor quality is caused by mixing of the Dakota Sandstone meteoric waters with gaseous and liquid igneous emanations related to the Quaternary igneous intrusives. The intrusives act like dams, and tend to slow movement of water through the Dakota Sandstone. Small to moderate yields, generally less than 10 gpm, are common for wells producing from the Dakota Sandstone. Large diameter wells have been known to produce up to 200 gpm (McLaughlin, 1956).

3) The Graneros Shale, a nearly impermeable formation, has specific capacities that are generally about 0.01 gpm/ft (1 gallon per minute per 100 feet of drawdown) east of the region. Water quality is poor, suitable only for livestock.

4) The Greenhorn Limestone depends on connected fractures and solution channels for its permeability. Little is known about its permeability, although the Greenhorn is highly fractured at its outcrops. These fractures probably decrease in abundance down the dip of the beds. Water quality of most wells producing from the Greenhorn is fair, and it tends to be hard. Very small quantities of water can be expected from wells producing from this formation.

5) The Carlile Shale is impermeable except for the silty and limy portion immediately below the Fort Hays Limestone Member. Water from this formation generally is of good quality except for an odor of hydrogen sulfide.

6) The Fort Hays Limestone Member has a low permeability, but probably would sustain low-yield wells. Fractures are abundant at outcrops of the member, but there is no evidence of solution channels. Wells should be located within five miles of the recharge area.

7) The Smokey Hill Marl Member is known to have low permeability. Several dry holes have been drilled into this formation. Some livestock wells producing 2 gpm are located east of the region. Water from this formation generally is poor with a high concentration of magnesium and sodium sulfates.

8) The Pierre Shale generally is saturated within a relatively short distance of the outcrops. The shale is highly impermeable and yields virtually no water. In places, several feet of weathered shale found immediately below the land surface transmit water somewhat more readily than fresh shale. Water quality is poor and unsuitable for human consumption. Some of the water has the odor of hydrogen sulfide, and all of it has sufficient sulfate that can be tasted (Griggs, 1948).

9) The Trinidad, Vermejo, Raton, Poison Canyon and Cuchara Formations all have similar aquifer characteristics. These formations generally are not known to yield significant quantities of water, although locally some wells have produced large quantities of fresh water. These formations are generally considered to be "dirty" and appear to have variable amounts of "clay fill." Porosity of the formations ranges from 2.0 to 18.0 percent. Penneabilities range from less than 0.1 to 20.0 millidarcies. Potential reservoir sandstones and conglomeratic beds in the Vermejo, Raton, and Poison Canyon Formations appear to be lenticular and encased in impermeable shales. Because of the region's dissected topography, the water-bearing sandstones and conglomerates usually are drained to the base of valleys. Niggerhead shaft, a 12 by 12-foot shaft sunk to a depth of 651 feet in Cucharas Valley west of Walsenburg, has yielded as much as 1,250 gpm, primarily from the basal conglomerate of the Raton Formation (McLaughlin, 1956). Water from these formations tends

to have moderate to high concentrations of fluoride and is generally soft.

10) Quaternary alluvium, pediment and terrace deposits, generally less than 100 feet thick, represent a good potential source of fresh water. These sediments consist of silt, sand, gravel, and boulders, and are recharged by infiltration of precipitation and influent stream conditions. The pediments occur as caps on the mesas northeast of Raton (Figure 3-20) and near the Vermejo Park Anticline. The recharge water collects in a thin zone at the base of the gravel, moves downdip, and is discharged as seeps and springs. Wells producing from the pediment deposits generally yield low to moderate quantities of water, usually of good quality. The alluvium deposits are found in essentially continuous bands along streams and rivers of the region. The permeability of these deposits is variable, but generally is very high. In both the pediment and terrace gravels, the zone of saturation is found at the base of the deposit, and normally is less than 10 feet thick. Water quality is variable but generally good. In isolated areas, the water can have excessive amounts of particulate matter or sulfates, depending mainly on the parent material of the alluvium. Alluvium deposits constitute the principal source of domestic water supplies in the Raton Mesa region.

11) Igneous rocks in the region include intrusive sill complexes and volcanic basalt flows, and are not thought to contain significant amounts of water. The intrusives are dependent on a poorly developed fracture system for the movement of water through the rock. However, if of sufficient lateral extent, dikes may impound groundwater moving through the formations they intrude. This situation has been observed in some parts of Colfax County in New Mexico (Griggs 1948). Movement of groundwater through volcanic complexes is less difficult, and results in thin water-bearing zones. Vertical water movement follows joints and fractures while horizontal movement follows both the fractures and interflow zones (Figure 3-21). Recharge from precipitation collects in these thin interflow zones, but there is a continuous loss to unsaturated

zones below. Water in the lava eventually emerges from the downdip end of the flows through seeps and springs. Wells and springs, although not a principal source of water, yield small to large quantities of fresh water. Flows up to 80 gallons per minute (gpm) have been recorded from springs issuing from a basalt flow. Wells generally yield less than 10 gpm.

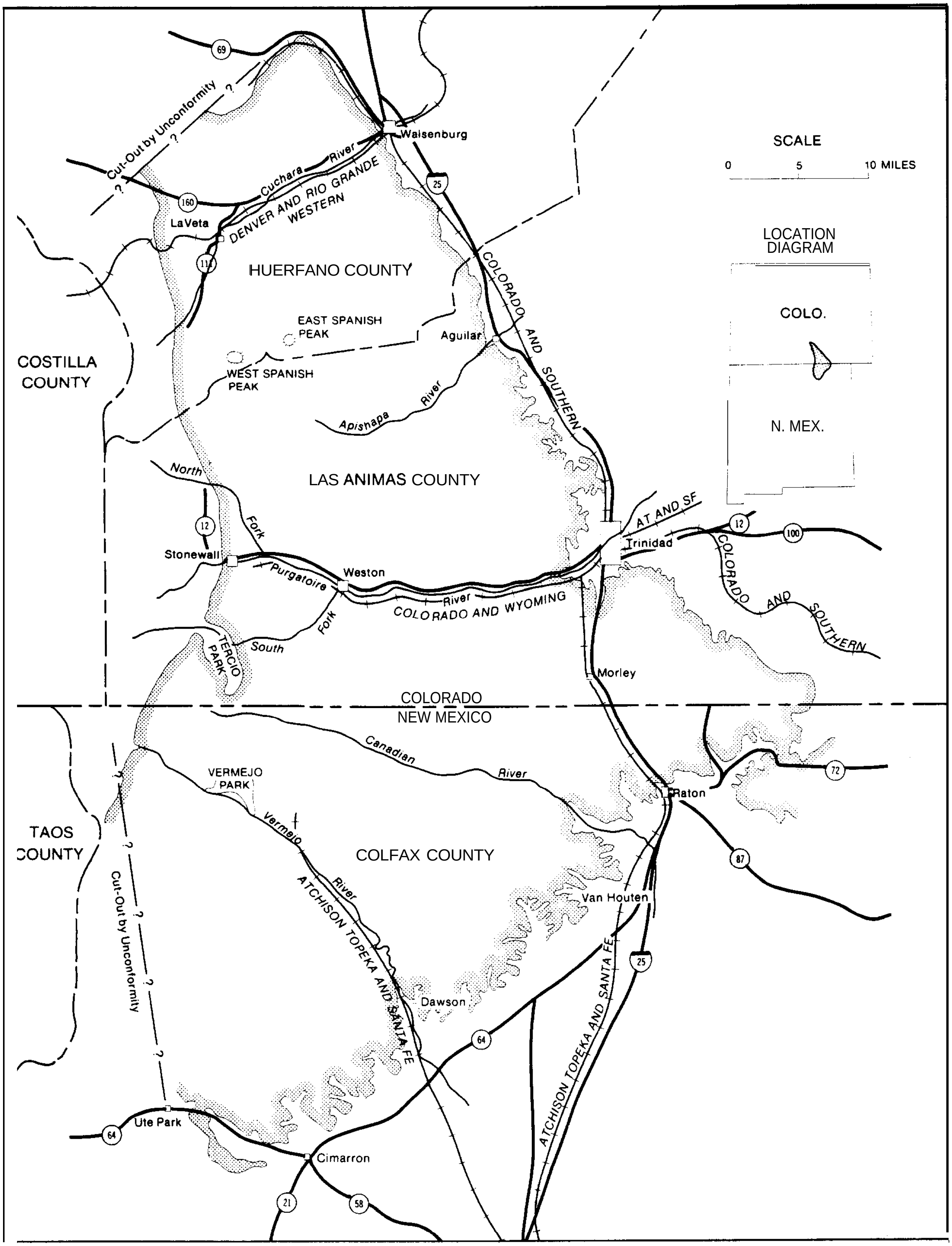


Figure 3-1. Raton Mesa Region of Colorado and New Mexico

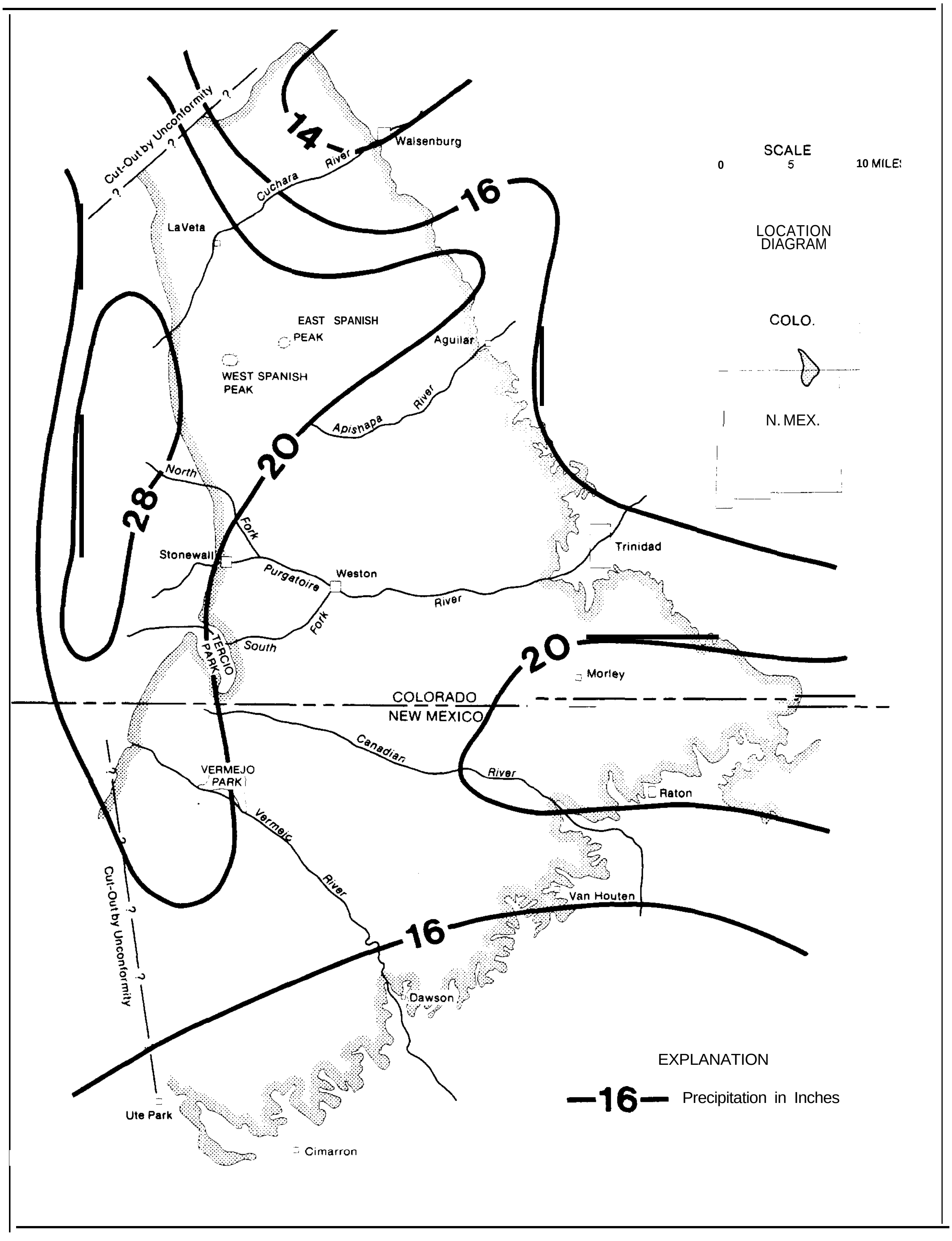


Figure 3-2. Isoline Map Showing Precipitation in the Raton Mesa Region (After Berry, 1968 and Haughton, 1972)

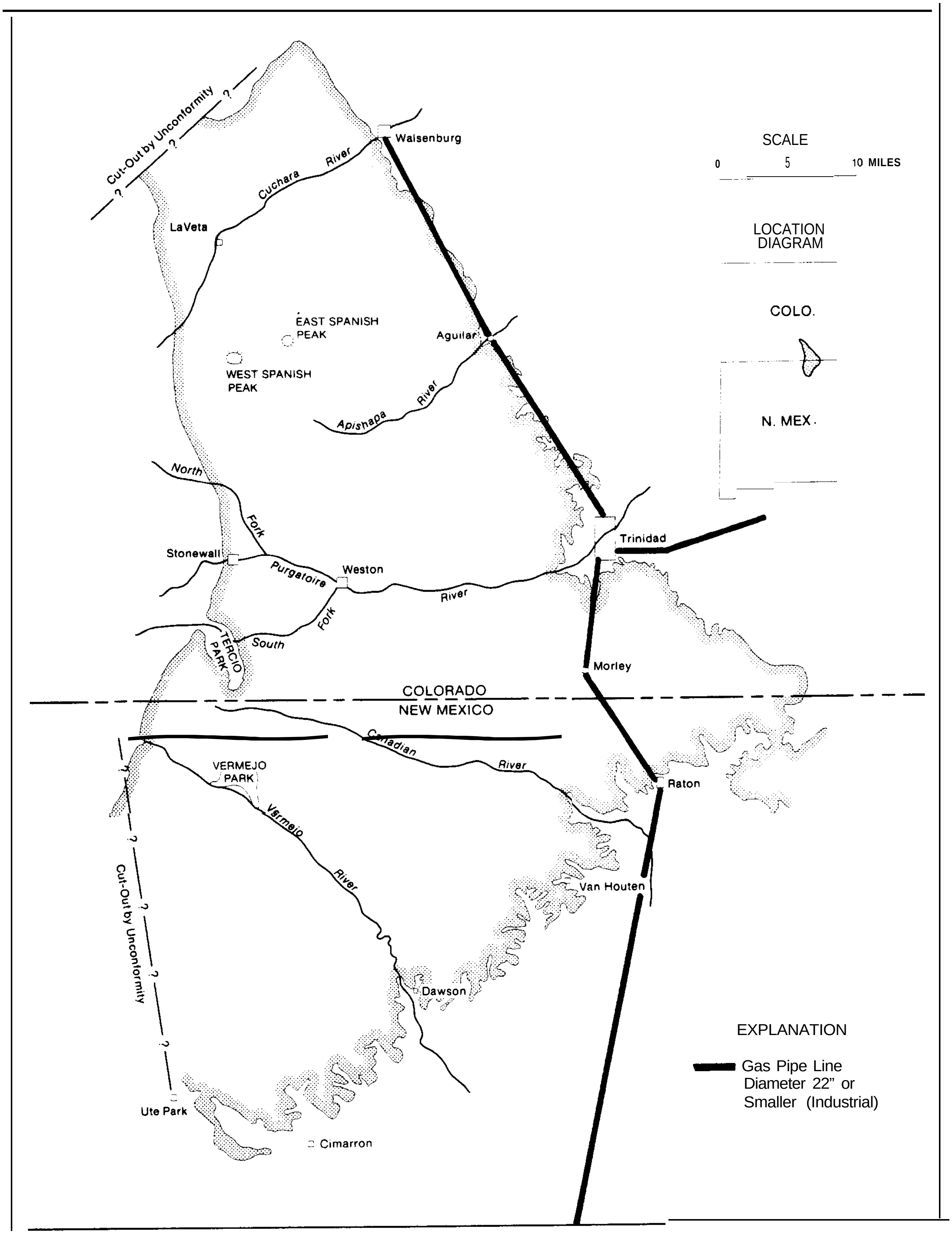


Figure 3-3. Gas Pipeline Network in the Raton Mesa Region
(National Atlas, 1974)

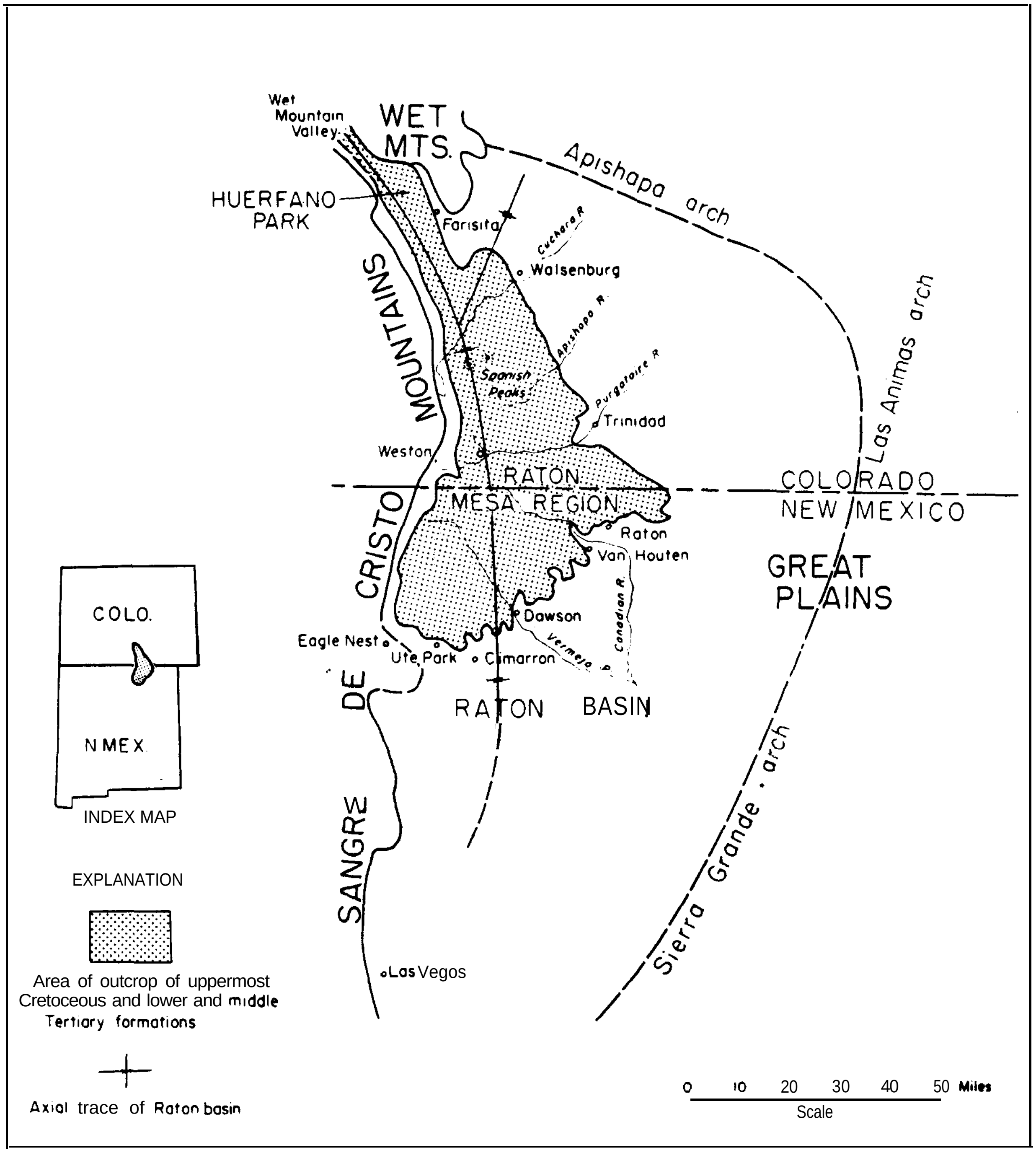
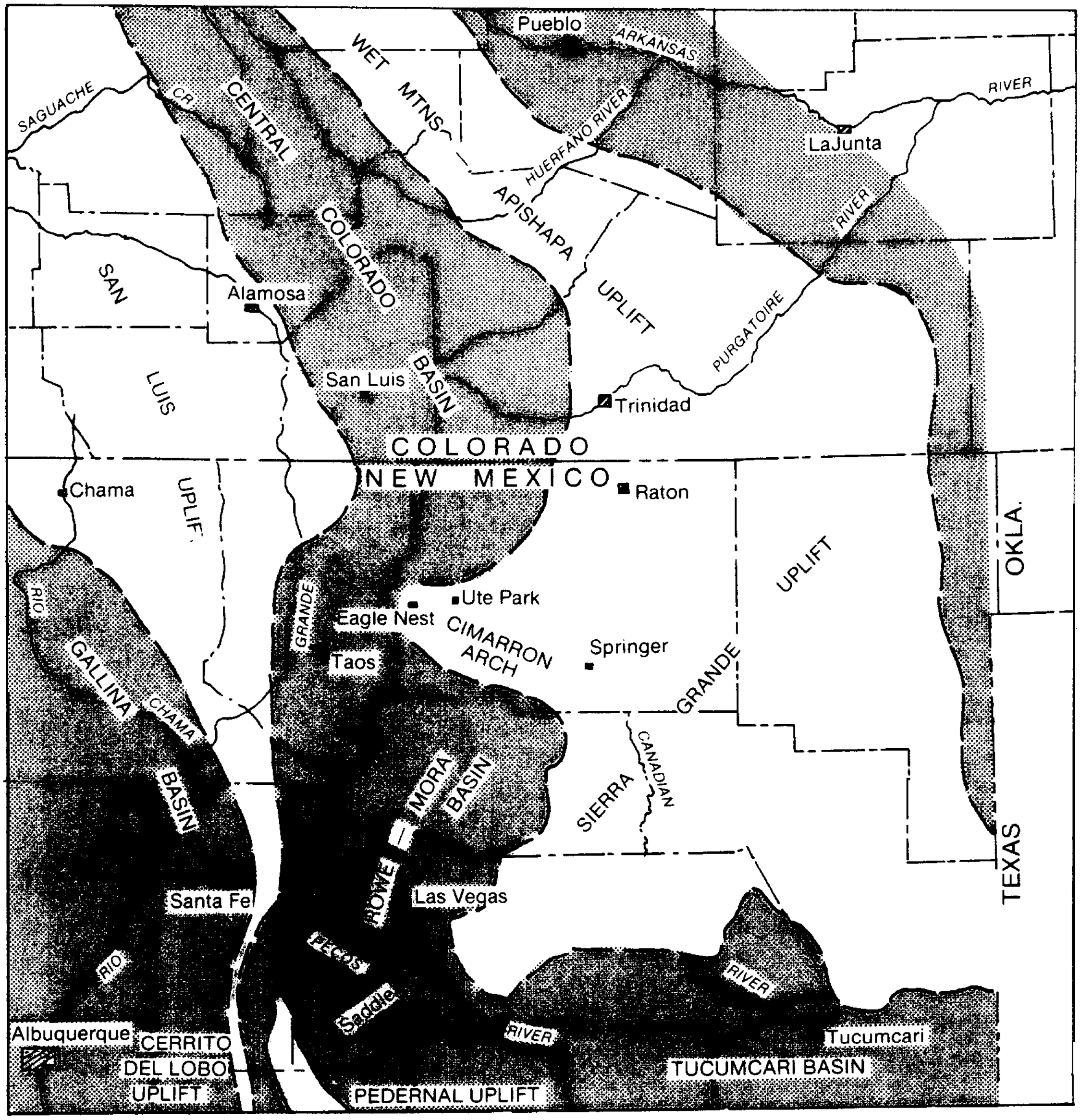


Figure 3-4. Map of the Structural Raton Basin of Colorado and New Mexico (Johnson and Wood, 1956) (Courtesy of RMAG)



EXPLANATION

Basin Areas

Pennsylvanian - Permian anticlines

Figure 3-5. Pennsylvanian and Permian Tectonic Elements of Southeastern Colorado and Northeastern New Mexico (Blatz, 1965) (Courtesey of AAPG)

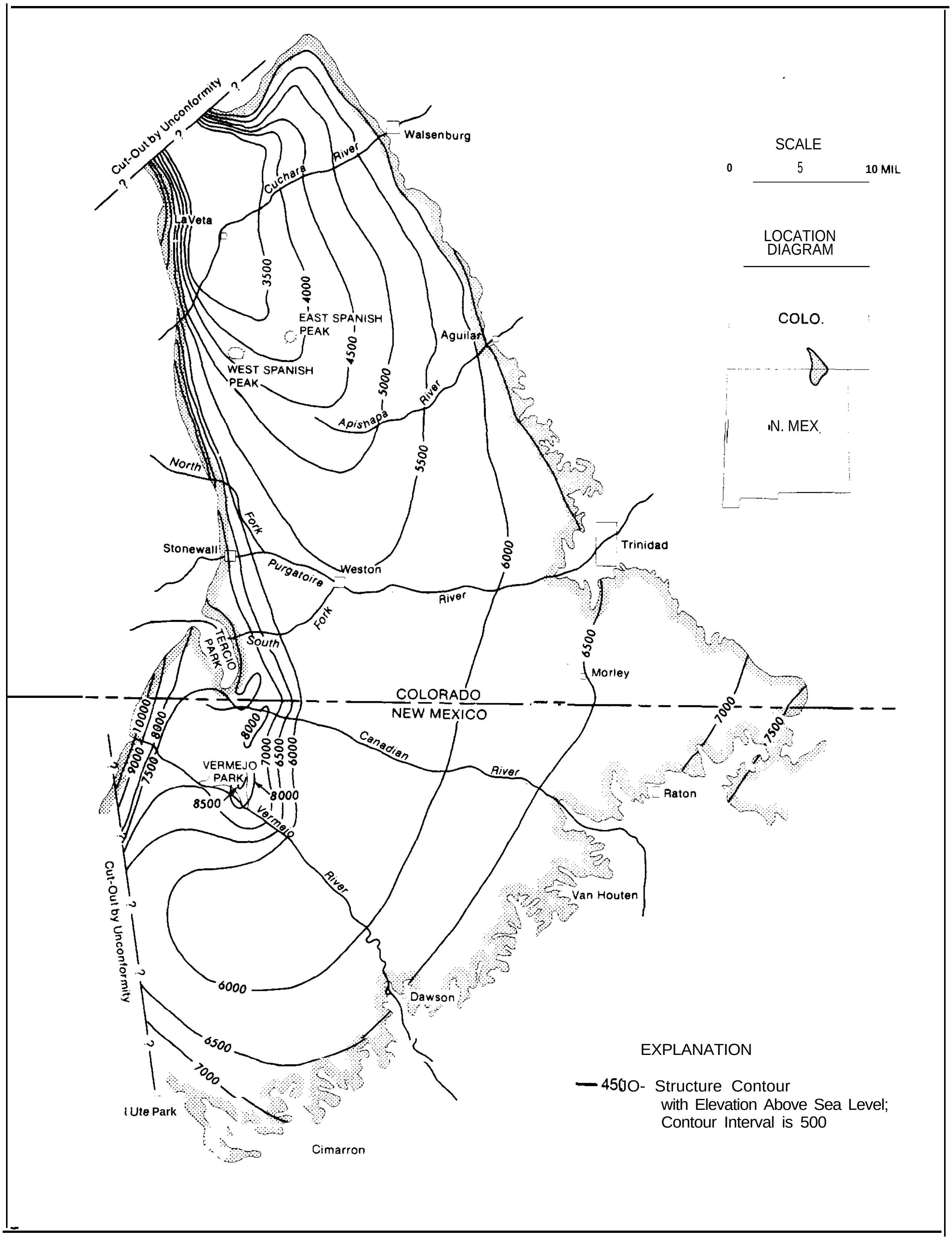


Figure 3-6. Structure Contour Map on Top of the Trinidad Sandstone in the Raton Mesa Region (After Tremain, 1980 and Pillmore, 1969)

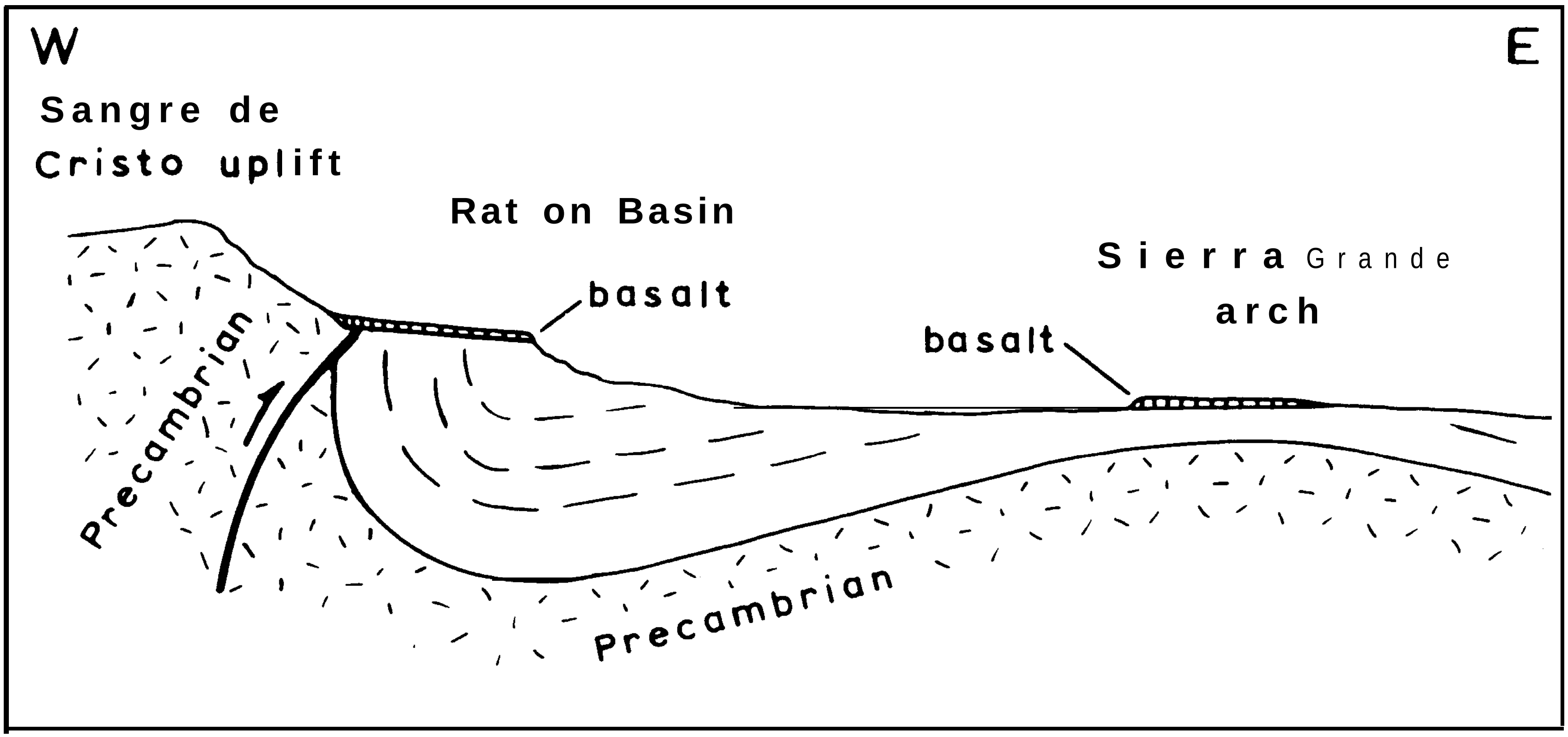


Figure 3-7. Diagrammatic East-West Structure Section Through the Sangre de Cristo Uplift, Raton Basin, and Sierra Grande Arch (Courtesy of New Mexico Geological Society, 1976)

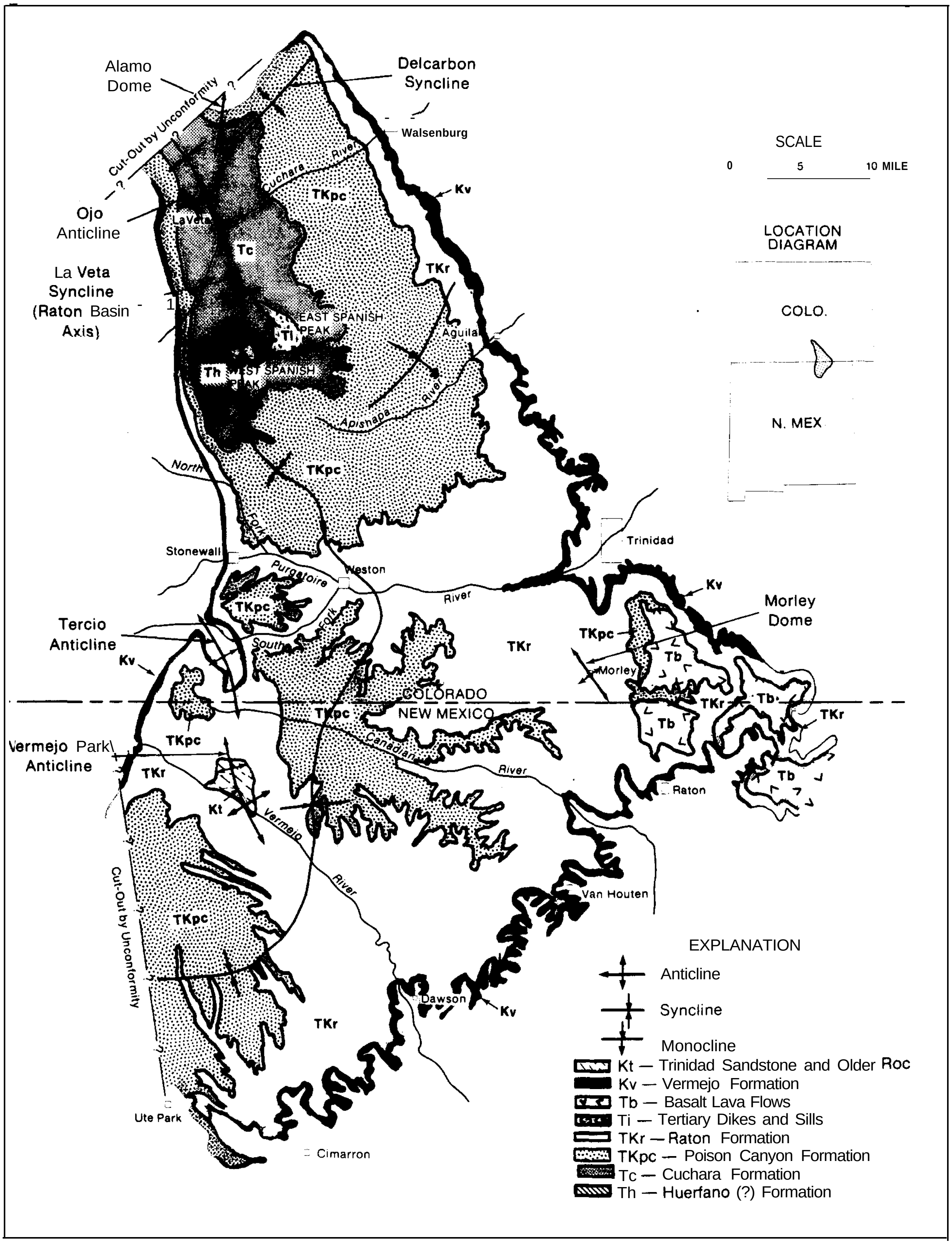


Figure 3-8. Geologic Map of Raton, Trinidad, and Walsenburg Coal Fields of the Raton Mesa Region (After Pillmore, 1969 and Johnson, 1959)

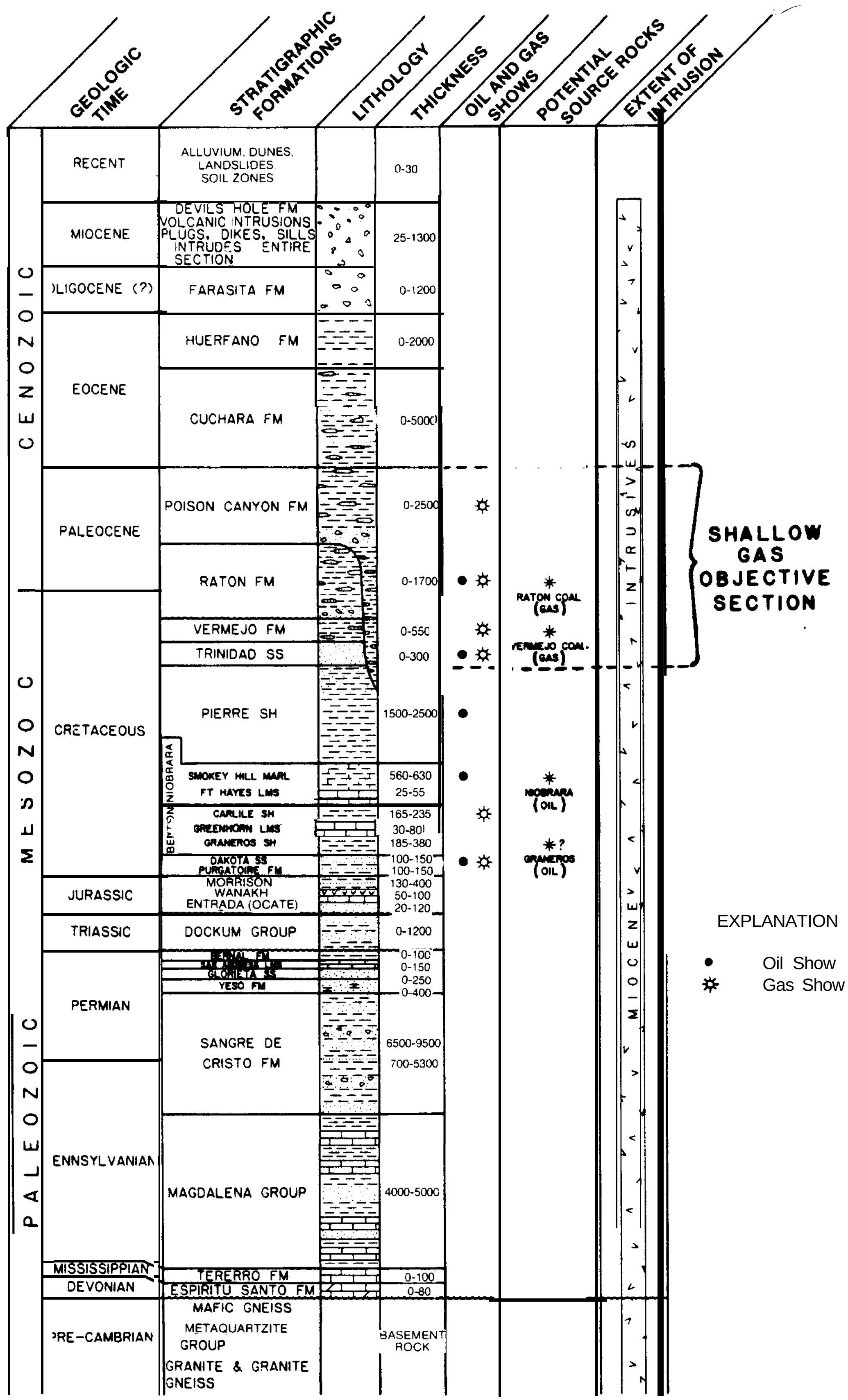


Figure 3-9. Generalized Stratigraphic Column of the Raton Mesa Region (After Dolly and Meissner, 1977)

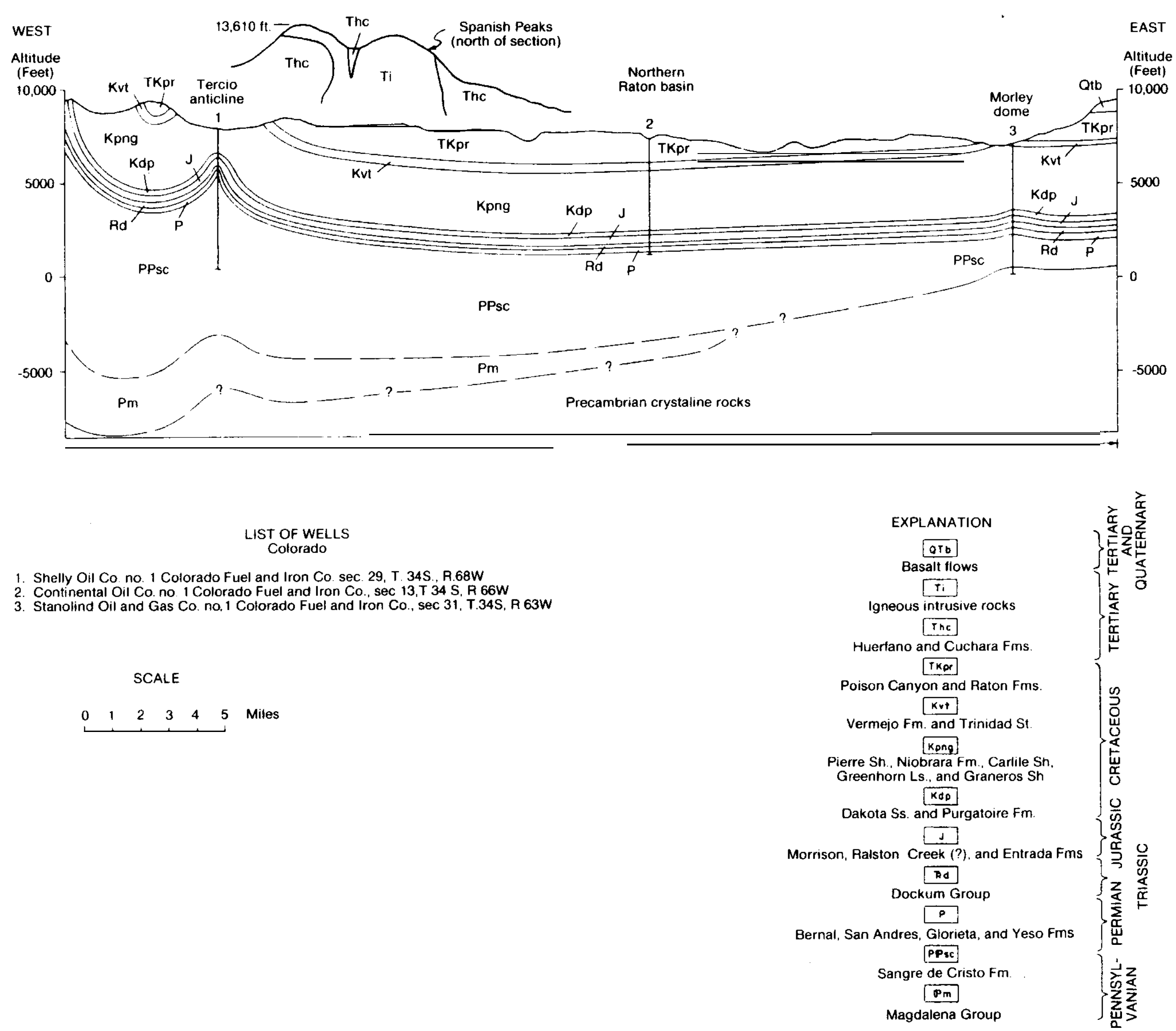
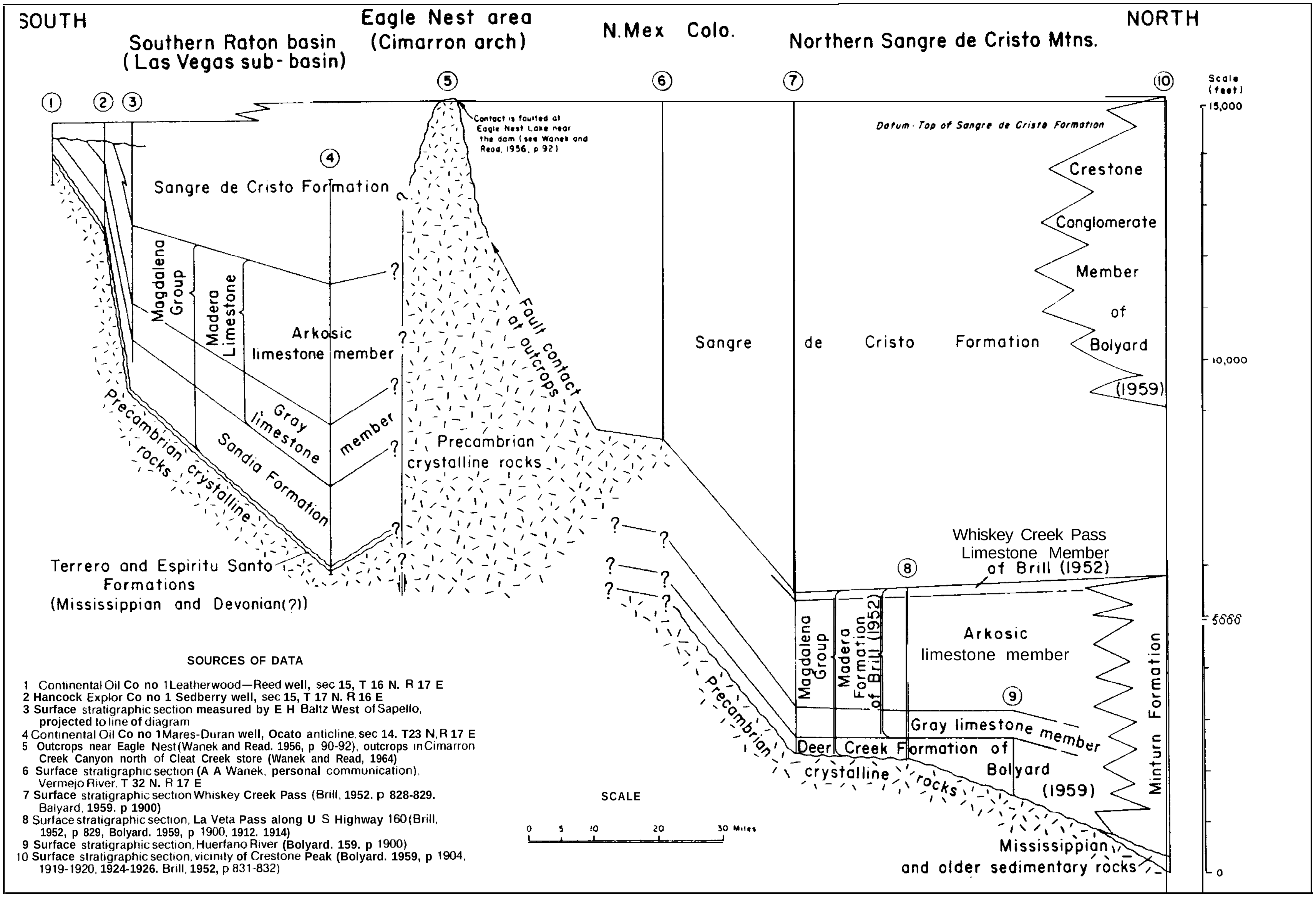


Figure 3-10. Diagrammatic East-West Cross Section of the Raton Basin (Courtesy of AAPG)



SOURCES OF DATA

1 Continental Oil Co no 1 Leatherwood—Reed well, sec 15, T 16 N. R 17 E
2 Hancock Explor Co no 1 Sedberry well, sec 15, T 17 N. R 16 E
3 Surface stratigraphic section measured by E H Baltz West of Sapello, projected to line of diagram
4 Continental Oil Co no 1 Mares-Duran well, Ocato anticline, sec 14. T23 N. R 17 E
5 Outcrops near Eagle Nest (Wanek and Read. 1956, p 90-92), outcrops in Cimarron Creek Canyon north of Cleat Creek store (Wanek and Read, 1964)
6 Surface stratigraphic section (A A Wanek, personal communication), Vermejo River, T 32 N. R 17 E
7 Surface stratigraphic section Whiskey Creek Pass (Brill, 1952. p 828-829. Balyard, 1959. p 1900)
8 Surface stratigraphic section, La Veta Pass along U S Highway 160 (Brill, 1952, p 829, Bolyard. 1959, p 1900, 1912, 1914)
9 Surface stratigraphic section, Huerfano River (Bolyard. 159. p 1900)
10 Surface stratigraphic section, vicinity of Crestone Peak (Bolyard. 1959, p 1904, 1919-1920, 1924-1926. Brill, 1952, p 831-832)

Figure 3-11. Diagram Showing Correlation of Paleoezoic Rocks
(Courtesy of AAPG)

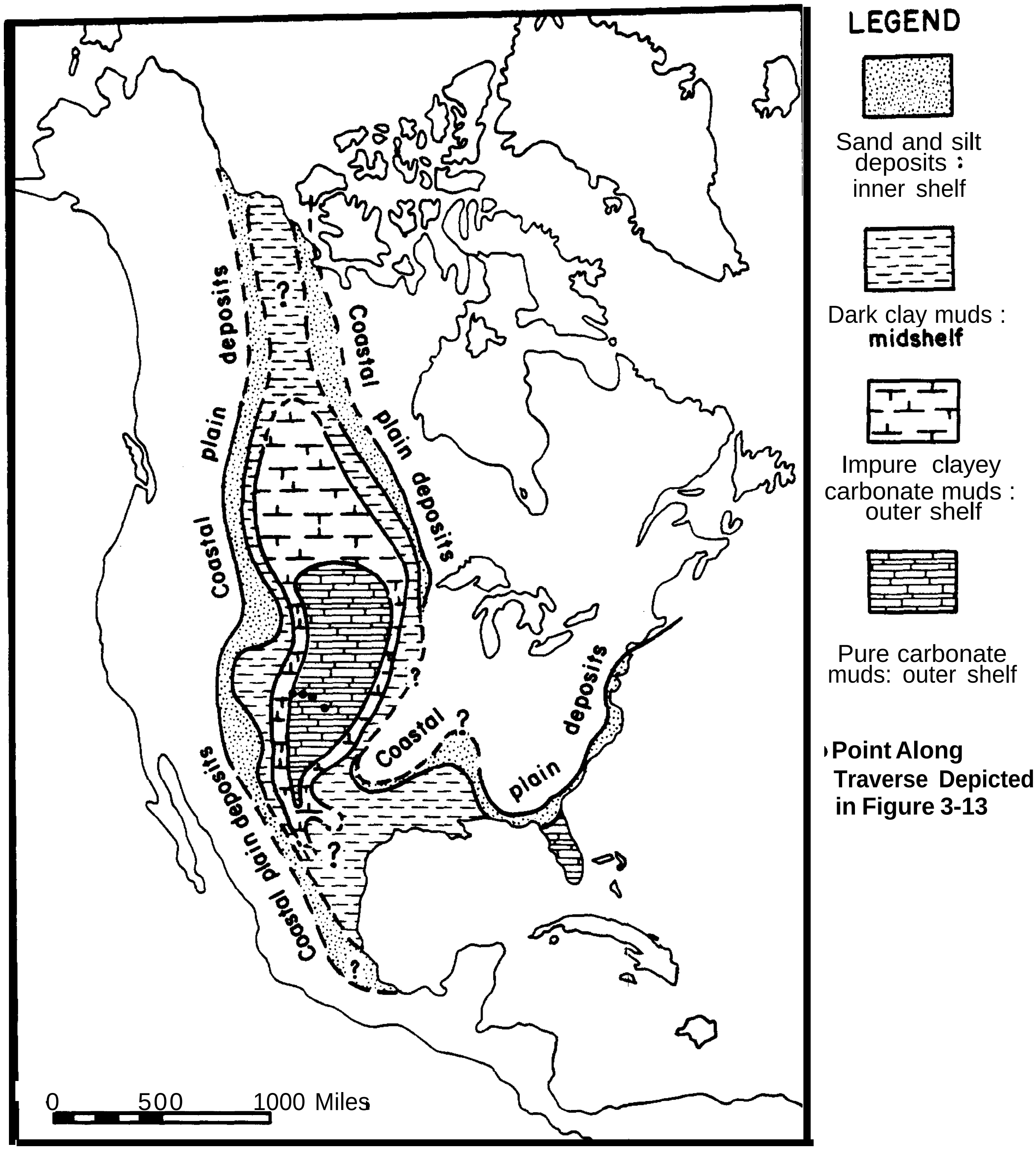


Figure 3-12. Sediment Distribution During Maximum Transgression, Greenhorn Marine Cycle, Western Interior Cretaceous Sea, North America (Courtesy of RMAG)

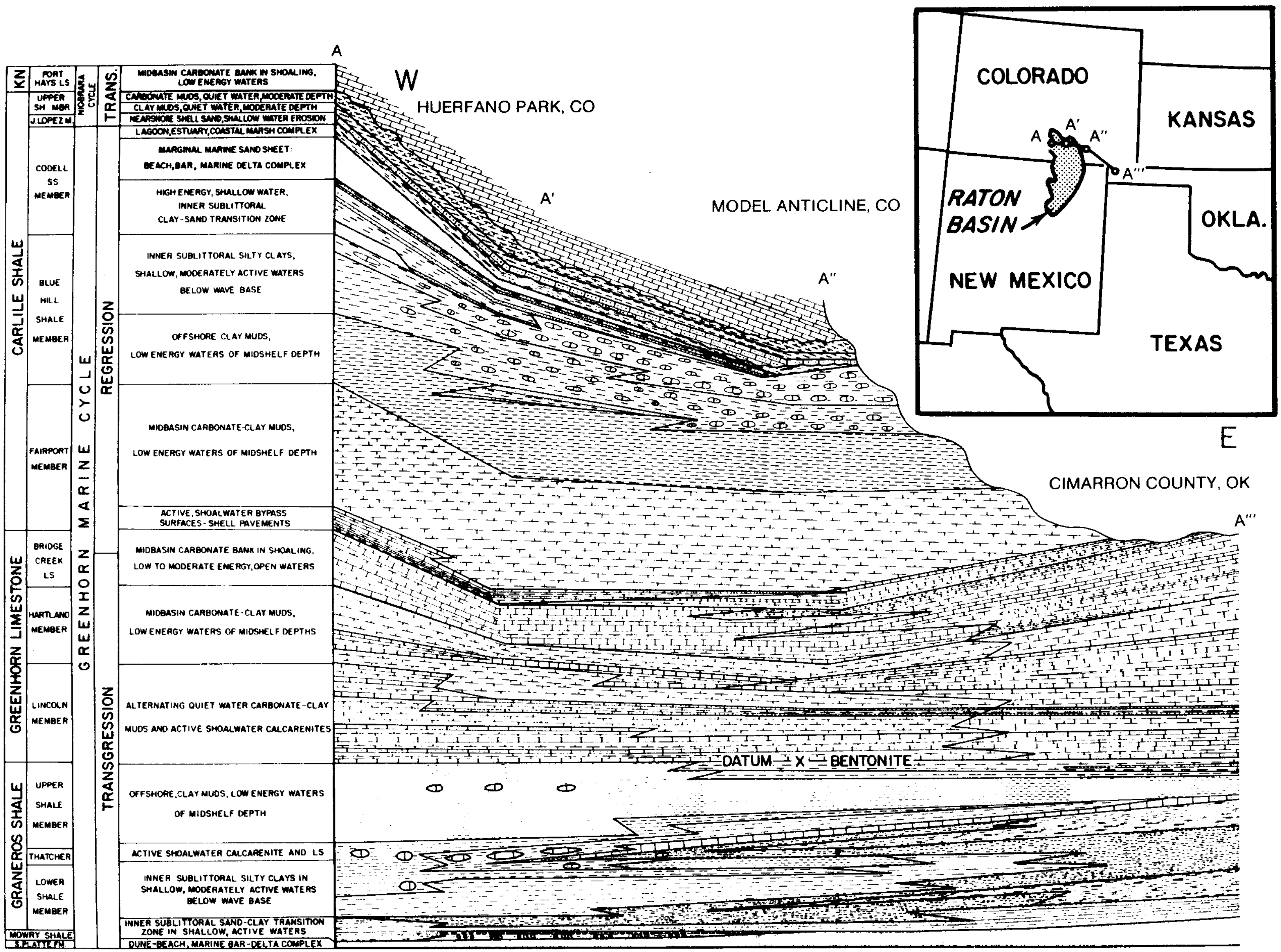


Figure 3-13. Lithofacies Relationships Along Traverse from Huerfano Park, Colorado to Cimarron County, Oklahoma. Refer to Figure 3-12 for General Location of Sections (Courtesy of RMAG)

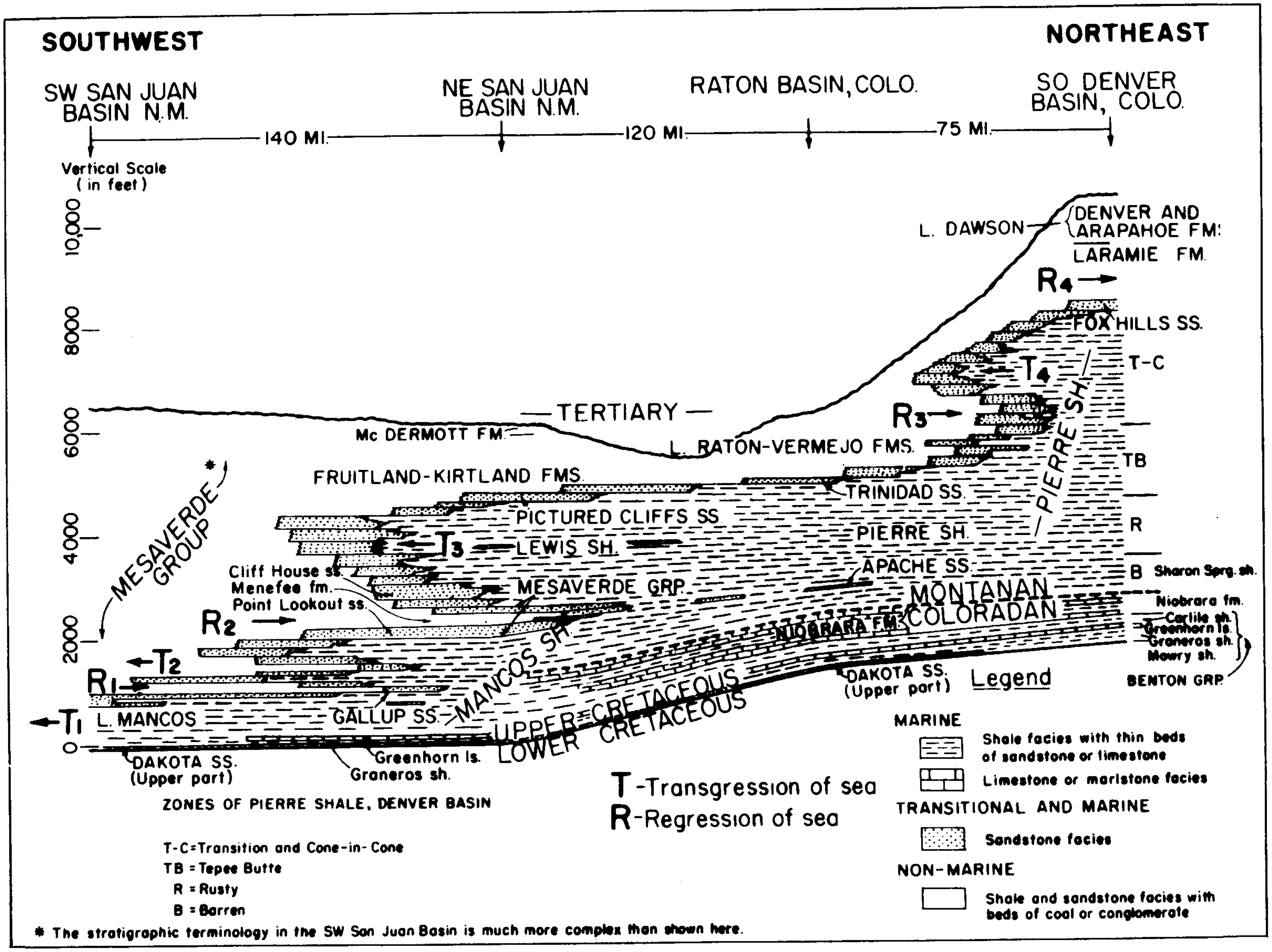


Figure 3-14. Restored Stratigraphic Section Across the Western Portion of the Cretaceous Depositional Basin Showing Transgressive-Regressive and Coal-Bearing Facies (Courtesy of AAPG)

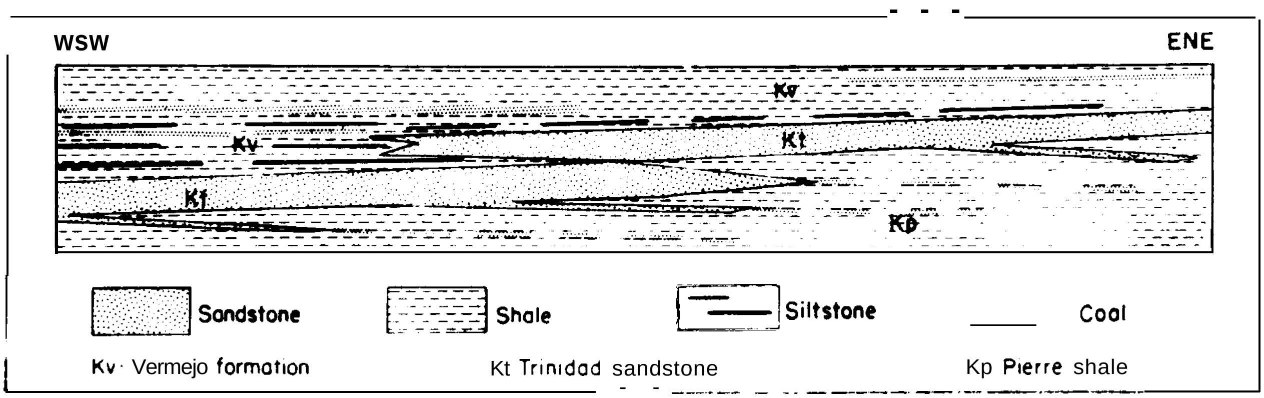


Figure 3-15. Contact Relationships of Vermejo Formation, Trinidad Sandstone, and Pierre Shale Between Cimarron and Dawson, New Mexico (Johnson, Dixon and Wanek, 1966)

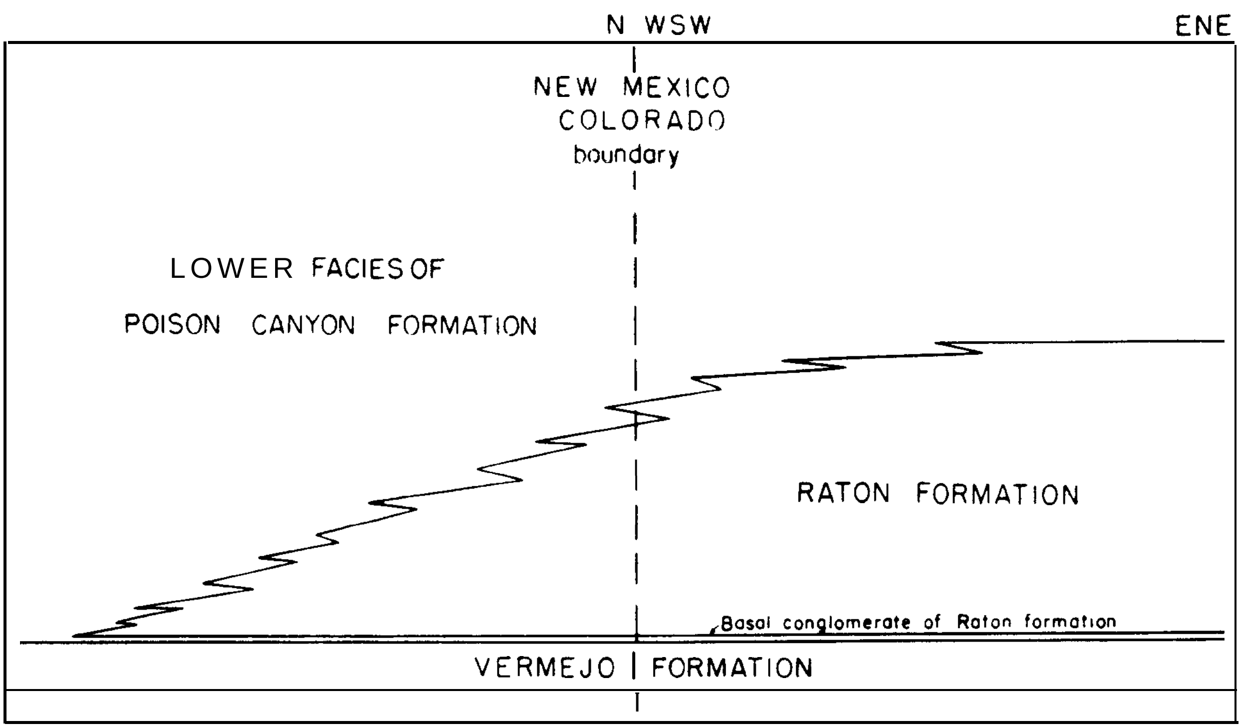


Figure 3-16. Inferred Inter-tonguing Relationships of Poison Canyon Formation and Raton Formation Between Weston, Colorado and Ute Park, New Mexico (Johnson, Dixon and Wanek, 1966)

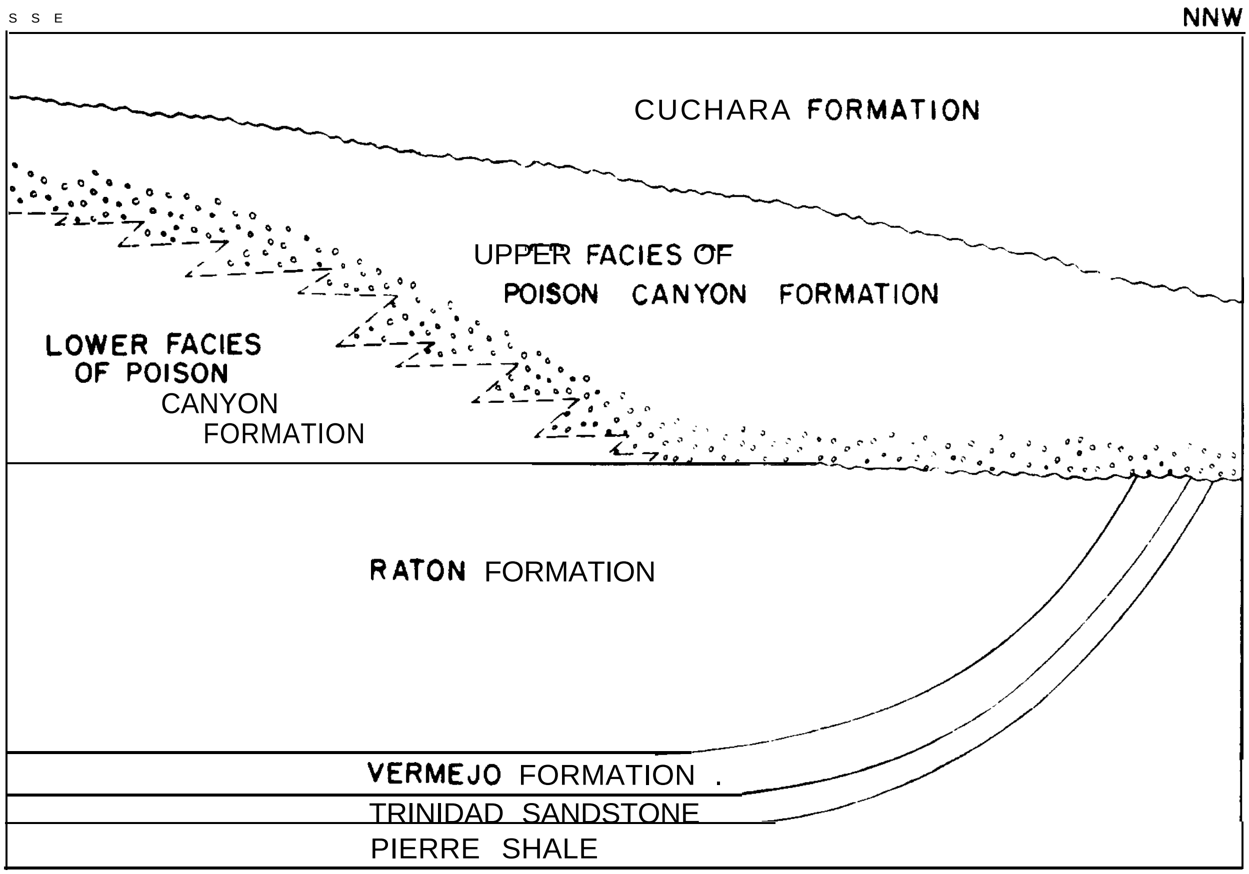
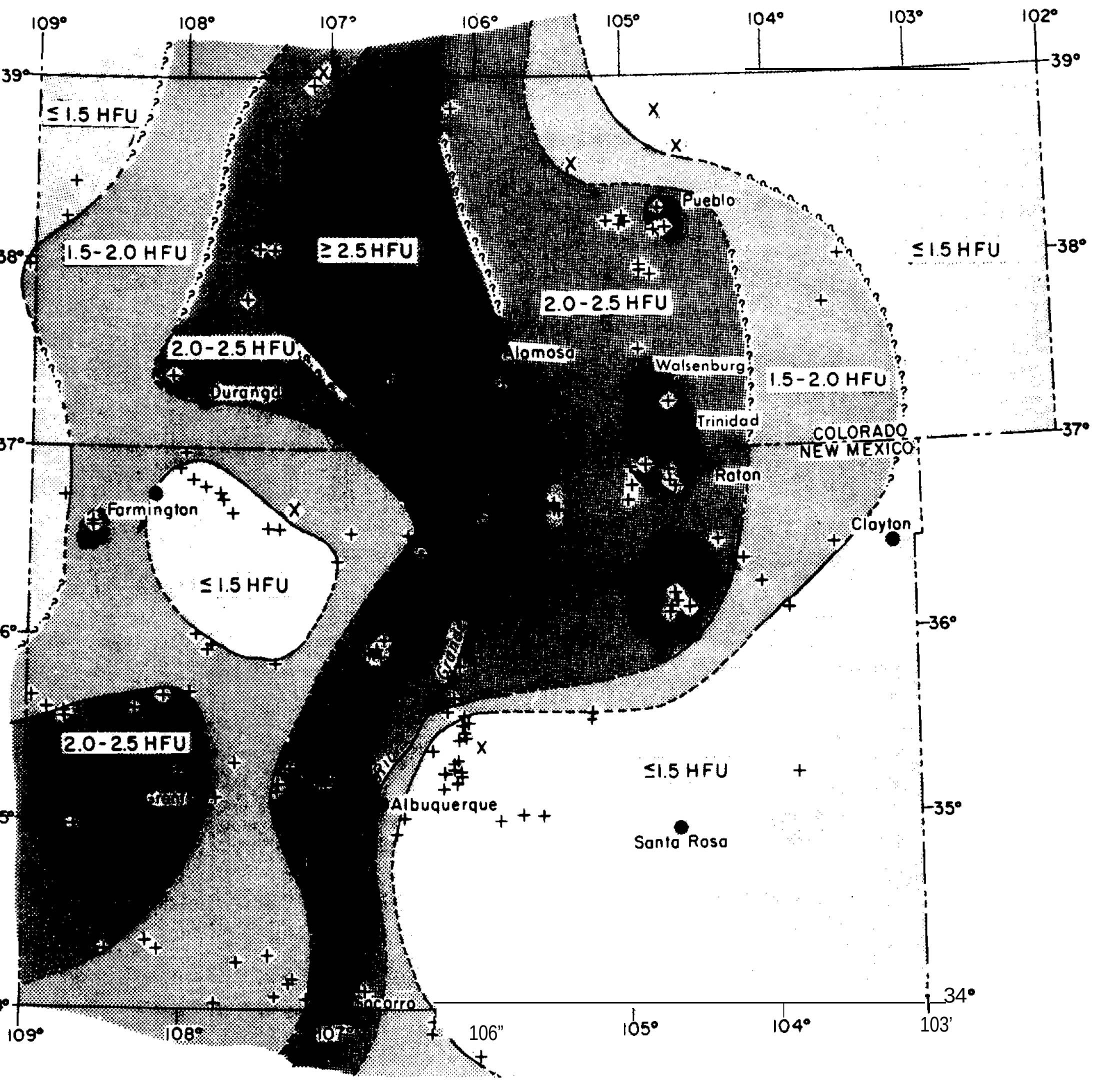


Figure 3-17. Contact Relationships Between Poison Canyon Formation and Underlying Tertiary and Cretaceous Formations from Vicinity of Trinidad, Colorado to Southern Part of Huerfano Park, Colorado (Johnson, Dixon and Wanek, 1966)



EXPLANATION
Contour Interval is 0.5 HFU

HFU	(Heat Flow Unit) Heat Flow is calculated by multiplying measured linear thermal gradients in drill tests by the corresponding average measured thermal conductivities.
+	Control site measured by the New Mexico Institute of Mining and Technology
X	Control site measured by other investigators
———	Area of good control
- - - - - -	Area where additional data may change location of contour but not character
?	Area of sparce data and ambiquity with regard to location and character of contour

Figure 3-16. Terrestrial Heat-Flow Contour Map of Northern New Mexico and Southern Colorado (After Edwards, et al, 1978)

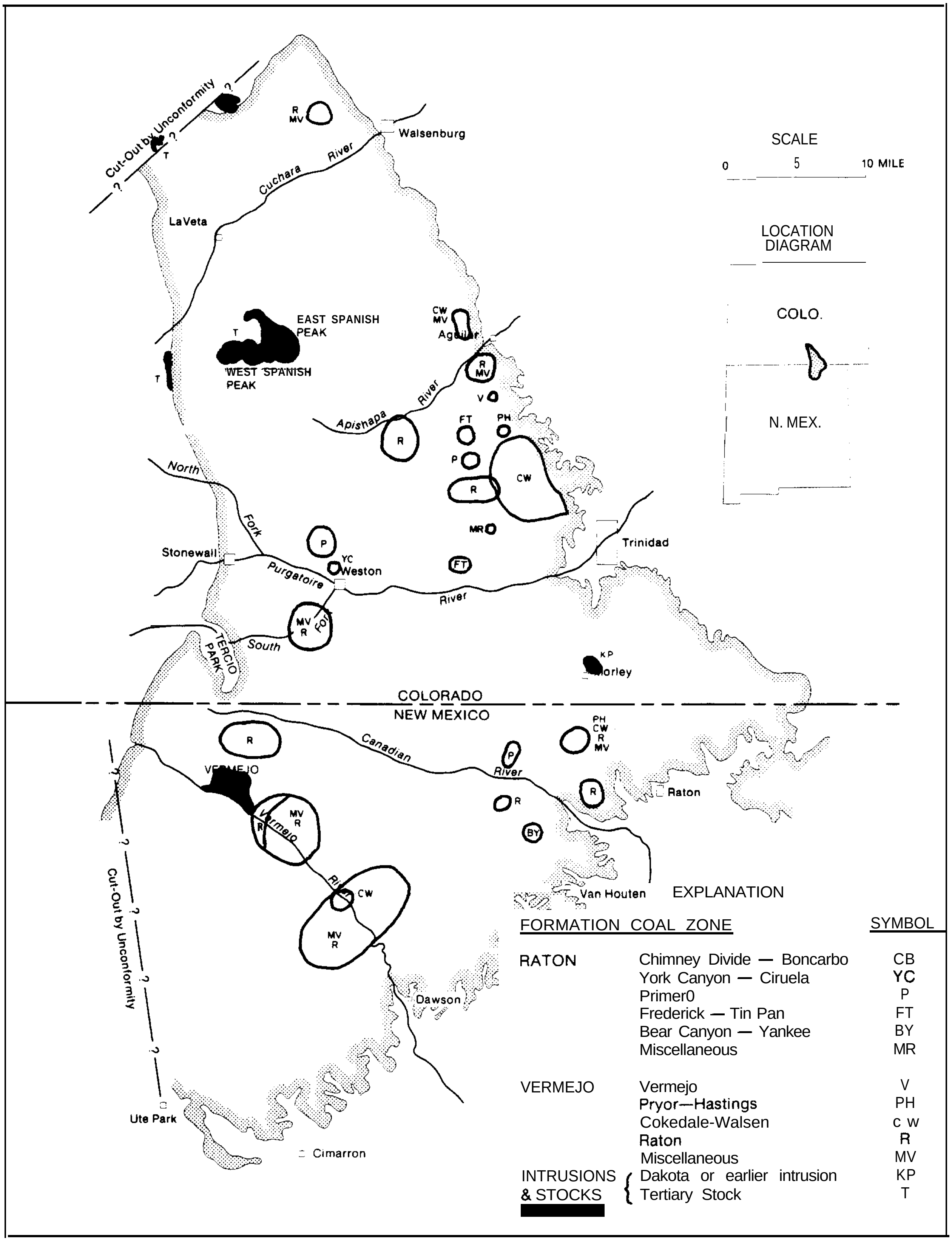


Figure 3-19. Areas Where Coal Has Been Destroyed or Altered to Natural Coke by Igneous Intrusions (Courtesy of Colorado Geologicat Survey)

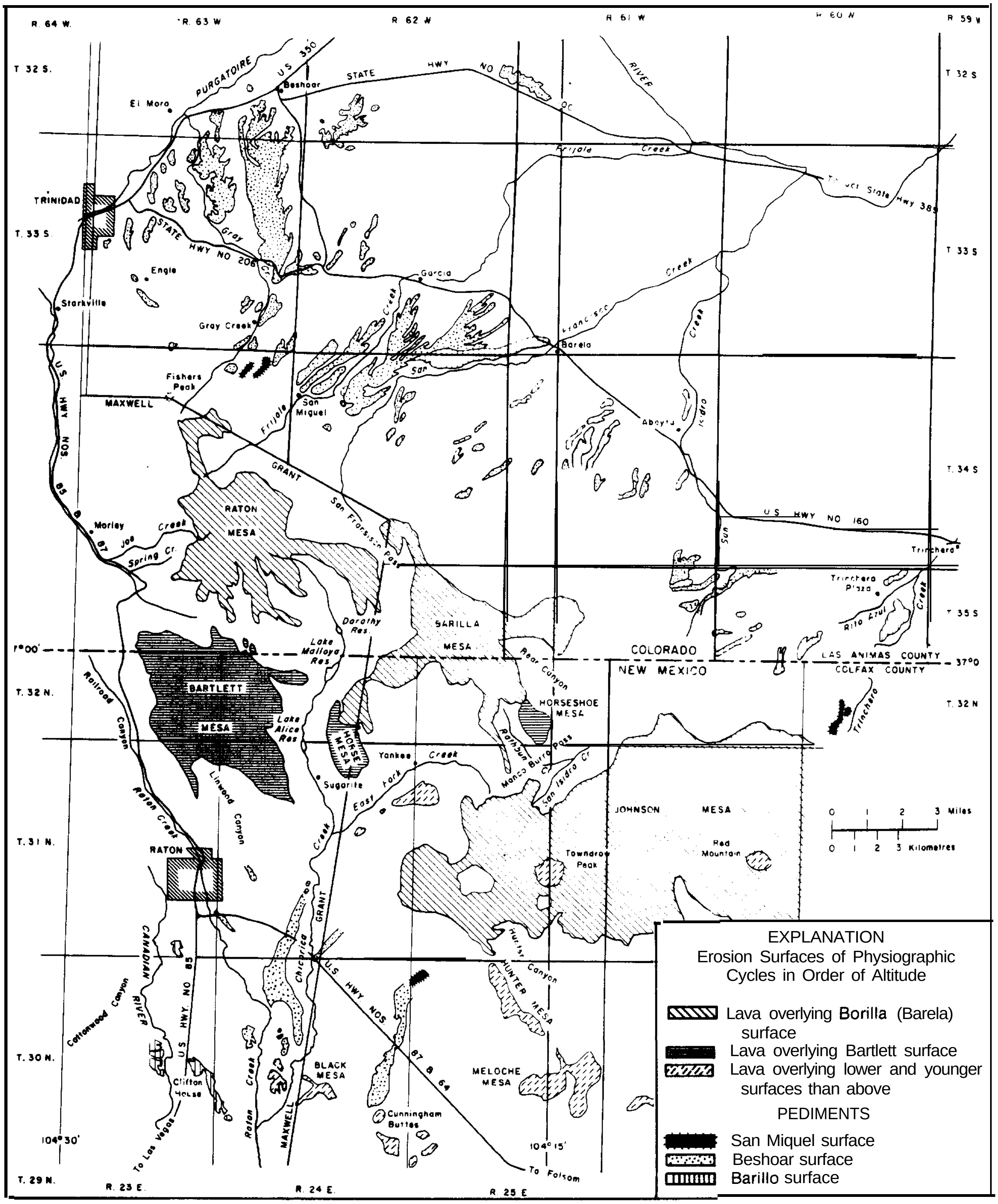


Figure 3-20. Map of Part of the Raton Mesa Region, Colorado and New Mexico, Showing Relative Ages, Location and Areal Distribution of Pediments and Older Lava-Covered Erosion Surfaces (Courtesy of Colorado School of Mines)

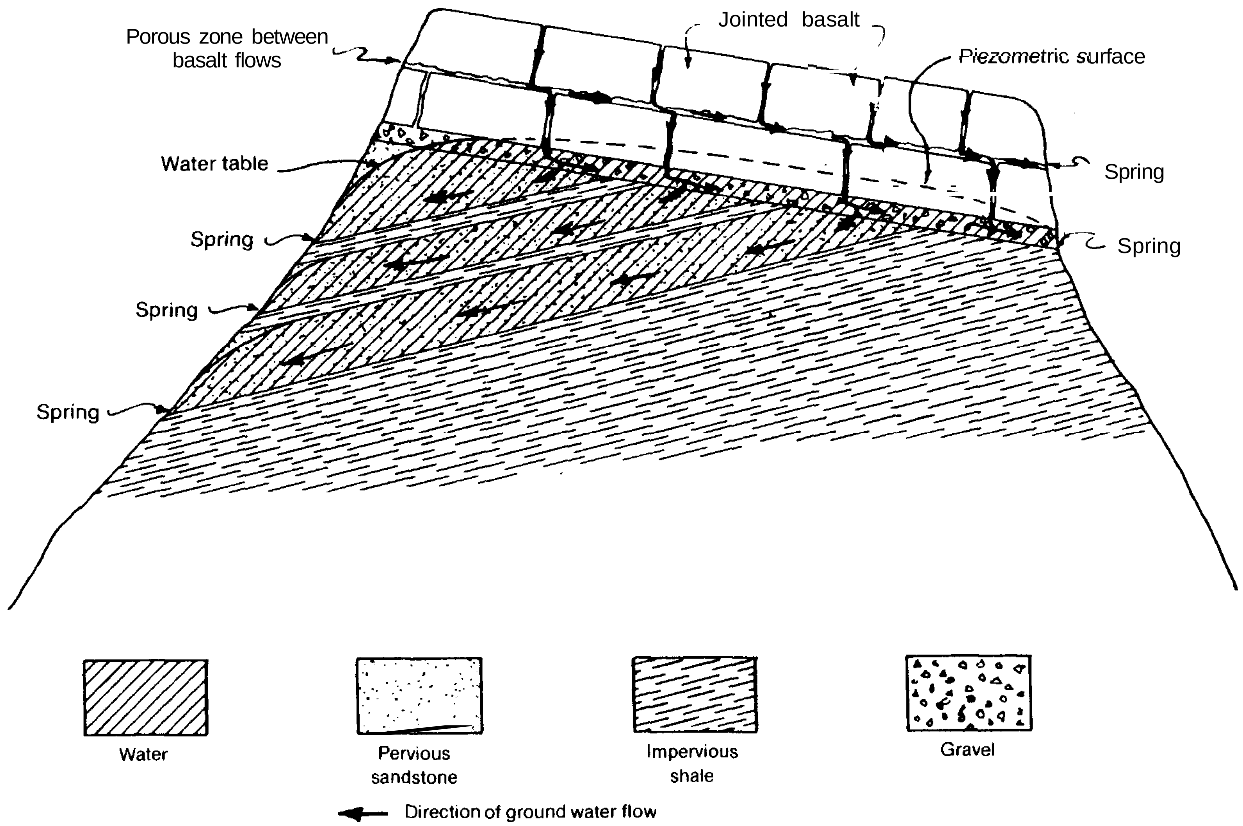


Figure 3-21. Diagrammatic Section Showing Movement of Ground Water Under the High Mesas of the Raton Mesa Region (Vertical Scale Greatly Exaggerated) (Griggs, 1948)

Table 3-1. Runoff Characteristics of Principal Rivers in the Raton Mesa Region

River	Drainage Area (mi²)	Average Discharge	
		cfs	acre-ft/yr
Vermejo River near Dawson, NM	301	19.2	13,980
Canadian River near Hebron, NM	229	8.3	6,040
Ponil Creek near Cimarron. NM	171	12.3	8,910
Purgatoire River near Trinidad, CO	795	87.2	63,180
Cucharas River near La Veta, CO	56	23.5	17,030

Additional Rivers for Which No Data Are Available in the Raton Mesa Region
Cimarron River — drains approximately 100 mi^2 in southwestern most tip of the region.
Apishapa River — drains approximately 4000 mi^2 which includes approximately 500 mi^2 in the north central part of the Raton Mesa Region.
Huerfano River — skirts north tip of the region draining approximately 50 mi^2.

4. THE COAL RESOURCE

4.1 REGIONAL (BASIN) CHARACTER

Coal in the Raton Basin was deposited during the Cretaceous and Tertiary Periods. During the Cretaceous Period, coal swamps developed along the margins of the shallow seaway. The Tertiary coal swamps developed within the intermontane Raton Basin.

The principal factors that influenced the formation of commercial coal deposits, as described by Weimer (1977), are:

1. Peat accumulated in predominantly clear, fresh-water environments. Muddy water accumulation sites can result in high ash contents in the coal.

2. The accumulation of land-derived plant material.

3. A balance must exist between the depositional interface and the groundwater table as the plant remains are deposited. If the organic matter is exposed to the atmosphere during its deposition, it will oxidize, and little or no peat will accumulate. A lake or bay will develop if the groundwater table is too high. Therefore, if peat is to accumulate, water must continually cover the organic debris, but not become deep enough for open circulation.

4. A favorable climate must exist for high rates of plant growth. Research indicates that a sub-tropical to tropical climate existed during Cretaceous time in Colorado.

5. The foregoing conditions must have persisted over long periods of time and over broad areas for thick commercial coals to develop.

Cretaceous coals in the western United States usually are associated with five primary depositional settings. These settings are transitional with one another and influence the lithology and stability of the roof and floor rocks of the coalbeds. Models developed by Collins (1976, 1977), Weimer (1977), Donaldson (1978,) Horne and others (1978), and Siemers (1978), are as follows:

1. Alluvial Plain
2. Upper Delta Plain
3. Lower Delta Plain
4. Barrier Island
5. Interdeltaic Embayment

Figure 4-l is a summary of previous U.S.G.S. geological studies conducted in the Raton Basin. Correlation of single coalbeds over long distances in this region is difficult because of their discontinuous nature. This difficulty in correlation has led to many discrepancies and much confusion in older descriptions of the region's coal resources. Therefore, correlation of coal zones in the Trinidad and Walsenburg Coal Fields as presented by Boreck and Murray (1979) (Figures 4-2 and 4-3) will be used for this report. Because of their discontinuous nature, and the inconsistency in their naming, several coalbeds are identified as occurring in more than one coal zone. In the following descriptions of the coal zones, coalbeds that appear in the zone name but are not discussed either are of minor importance or have been mined-out. Due to the large number of coalbeds present in several of the zones it would be impractical to include all of them in the zone name.

The coalbeds are exposed along the coal region's boundaries and in canyons cut by streams. The coalbeds dip toward the center of the basin so that a large portion of the coal lies at depths exceeding 1,000 feet. Coalbeds are more numerous, thicker, and considerably more extensive in the Vermejo Formation than in the Raton Formation. Thick coalbeds in the Raton Formation generally are lenticular, local in extent, and are found mainly in the lower part of the formation. Roehler and Danilchik (1980) believe the discontinuous nature of the Raton Formation coalbeds resulted from compaction faults and fluvial scouring.

Coals of the Raton Basin generally range in rank from high-volatile C bituminous to medium-volatile bituminous. Igneous intrusions have locally altered coalbeds to anthracite. In other areas coalbeds have been metamorphosed to prismatic coke, and near Raton, potentially commercial graphite was formed by the metamorphism of the Raton coalbed in the Vermejo Formation. The thin, relatively rare coalbeds of the Poison Canyon Formation are lignitic in rank.

The Raton and Trinidad Coal Fields yield coal that forms a high quality coke; however, coal from the Walsenburg Field to the north generally is of non-coking quality. The Huerfano-Las Animas County line in Colorado has been a convenient boundary between coking and non-coking coal deposits (Figure 4-4). Coal analysis indicates a general and continuous increase in rank from the Walsenburg field southward to the Trinidad field. The Huerfano-Las Animas County line is considered to be only an approximate boundary between coking and non-coking coal (Goolsby, Reade, 1979). Figure 4-5 illustrates the general rank of coalbeds occurring along the Purgatoire River in the Trinidad Coal Field. The range of proximate analyses for coals from both the Vermejo and Raton Formations is as follows:

Volatile Matter (%)	25 - 40
Fixed Carbon (%)	48 - 60
Ash (%)	7 - 20
Sulfur (%)	0.5 - 1.5
Btu/lb (Moist, Mineral Matter Free)	12,500 - 15,200

Tables 4-1 and 4-2 show the range of analyses of coalbeds in the Vermejo and Raton Formations. Coal that has been locally altered by igneous intrusives generally has high ash, and lower calorific and volatile matter values.

Coalbeds of the Vermejo Formation consist of vitrain alternating with bands of fusain and durain. Partings in the coalbeds consist of bony coal, carbonaceous shale, and carbonaceous siltstone. Impurities, common in most of the beds, are mainly pyrite and elemental sulfur (?) with some silt and sand.

Coalbeds'of the Raton Formation consist of approximately equal parts of durain and vitrain with lesser amounts of fusain. Partings of bony coal, carbonaceous shale, and carbonaceous siltstone are more common in the Raton Formation. Coal of the Raton Formation is generally pure, but small quantities of pyrite, elemental sulfur (?), quartz sand grains, and limonite are generally present.

Overburden thickness varies greatly throughout the basin and is dependent upon local topography and position within the basin. Minable reserves of coal occur in the vicinity of the regions periphery, in a few structural uplifts, and along the major stream drainages (Figure 4-4). Coalbeds with individual thicknesses up to 14.5 feet, and an estimated average cumulative thickness of 15 feet, are believed to underlie about 2,100 square miles in the basin from the outcrops to maximum depths of

3,000 to 4,000 feet at the basin axis near the Spanish Peaks. Only the southwesternmost part, which totals approximately 80 to 100 square miles, is barren. Sills that intruded into and along the coalbeds destroyed hundreds of millions of tons of coals (Pillmore, 1969b).

4.2 STRATIGRAPHIC CHARACTER

Because of the discontinuous nature of coalbeds in the Raton Basin region, and the lack of correlation work between mines, very little is known about the extent of the coalbeds. Consequently not much information on a basin-wide basis has been published. Original reserves have been calculated for small portions of the region based on outcrop descriptions and measured sections in mines. These reserves are presented in Tables 4-3 through 4-5. Descriptions of all coalbeds named in the region would be voluminous and repetitive; therefore, only the most important coalbeds and coal zones of each formation are described below.

4.2.1 Raton Coal Field

Total resource estimates for the Raton Field range from 1.5 billion tons (Wanek, 1963) to 4.8 billion tons (Reade, et al, 1950). Measured sections of the Raton Coal Field are presented in Figures 4-7 through 4-14. Figure 4-6 identifies the location of the lines of sections in the Raton Coal Field. Table 4-l presents ranges of typical analyses of coalbeds in the Raton Coal Field.

4.2.1.1 Vermejo Formation

The Vermejo Formation contains from zero to three coalbeds greater than 14 inches thick in most of the coal field. These coalbeds are lenticular, irregular in thickness, and are interbedded with shale and siltstone. The coal is generally brittle, friable, and has a bright luster. It has prismatic or cubic cleating and platy cleavage. Floors and roofs of the mines are generally carbonaceous siltstone, sandstone, and conglomeratic sandstone (Lee, 1924).

4.2.1.1.1 Raton Coalbed

The Raton coalbed was named by early miners for the town of Raton, and the name is commonly applied to commercial beds found at or near the base of the Vermejo Formation throughout the Raton Coal Field, regardless of whether or not the beds can be traced back to the Raton area. In areas where two or more beds are present, the thickest bed usually is called the Raton bed. In some areas it may be as much as 14.5 feet thick (Lee, 1924) and is the most extensive and valuable bed in the Raton Field (Figures 4-7 and 4-8). The beds are not continuous although they lie at the base of the Vermejo Formation. The beds become progressively older to the west. The coalbeds are grouped in large, elongate, pod-shaped deposits, some of which have been intruded by igneous sills and partially destroyed.

Early mining of the Raton bed was concentrated along the Dawson, Koehler-Van Houten, and Gardner trends, utilizing the convenience of side-hill entry and railroad transportation. The Raton coalbed probably correlates with coalbeds found in the Cameron, Lower Bunker coal zone of Boreck and Murray (1979) (Figure 4-2).

4.2.1.1.2 Vermejo Coalbed

The Vermejo is a thick coalbed near the top of the Vermejo Formation at Vermejo Park, and in the upper part of the formation in the Castle Rock District (Figure 4-9). It is more irregular in thickness and distribution than the Raton coalbed. It is generally restricted in occurrence to areas where the Vermejo Formation is thicker than 250 feet.

4.2.1.1.3 Sugarite Coalbed

Mined primarily in the vicinity of Raton and Sugarite, New Mexico, this coalbed is believed to be located in the lower part of the Vermejo Formation, approximately 85 feet above the top of the Trinidad Sandstone. It is not located in the normal stratigraphic interval of the Raton or Vermejo coalbeds, and it has not been determined whether the Sugarite bed is in the Raton Formation and equivalent to the Vermejo bed or whether it is an intermediate bed in the Vermejo Formation. Figure 4-10 illustrates sections of the Sugarite coalbed measured by Lee (1924), in the Sugarite Canyon, New Mexico.

4.2.1.2 Raton Formation

Coalbeds of the Raton Formation are generally thinner, more lenticular, irregular in thickness, and more widely spaced than coalbeds of the Vermejo Formation. The roof and floor rocks are generally shale and bony coal, although at some localities the roof is a thick sandstone bed (Lee, 1924).

4.2.1.2.1 Potato Canyon Coalbed

The Potato Canyon coalbed ranges from 0 to 8 feet in thickness, is characterized by numerous shale partings, and lies from 100 to 150 feet stratigraphically above the Tin Pan coalbed. An exploration mine, the Potato Canyon, was opened by Kaiser Steel Corporation in Potato Canyon to test roof conditions and study mining costs. This coalbed is not of metallurgical grade, and will be used as steam coal by Kaiser Steel Corporation (Carter, 1980).

4.2.1.2.2 Tin Pan Coalbed

The Tin Pan coalbed underlies an area of 40 square miles 4 miles west of Raton, and ranges in thickness from a streak to more than 8 feet. It usually contains one or more partings as much as 4 feet thick (Figure 4-11). The Tin Pan lies 700 feet stratigraphically above the Trinidad Sandstone and crops out in many canyons along the Canadian River. Even though the Tin Pan coalbed has been mined for several years, substantial coal resources still remain in the ground.

4.2.1.2.3 Yankee Coalbed

The Yankee coalbed is thinner and less extensive than the Tin Pan, and is characterized by shale partings. It is approximately 300 to 400 feet stratigraphically above the Trinidad Sandstone. The Yankee and Tin Pan are possibly equivalent stratigraphically, indicating a thinning of the lower zone of the Raton Formation. Several measured sections of the Yankee coalbed are presented in Figure 4-12.

4.2.1.2.4 Left Fork Coalbeds

The Left Fork coalbeds are two beds about 50 feet apart, exposed on the steeply dipping east flank of the Vermejo Anticline in the Left Fork of York Canyon northeast of Vermejo Park (Figure 4-13). The lower coalbed is about 1,250 feet above the top of the Trinidad Sandstone. The upper bed is the thicker and more persistent of the two, and ranges in thickness from 5 to nearly 8 feet throughout much of its known extent. Estimated resources in the Left Fork upper bed, where it is greater than 3.5 feet in thickness, total almost 25 million tons (13.3 MT measured, 5.5 MT indicated, 5.9 MT inferred) (Pillmore, 1969b).

4.2.1.2.5 Cottonwood Canyon Coal Zone

The Cottonwood Canyon coal zone underlies an area of 10 square miles in Cottonwood and Caliente Canyons (Figure 4-13). The Cottonwood Canyon bed ranges in thickness from a few inches to 7 aggregate feet of coal in a 9-foot zone, and is characterized by several shale partings. An estimated 51 million tons of coal (19 MT measured, 23 MT indicated, 9 MT inferred) are contained in the Cottonwood Canyon bed (Pillmore, 1969b).

4.2.1.2.6 Ancho Canyon Coalbed

The Ancho Canyon coalbed crops out in an area of 16 square miles in the vicinity of Ancho, Salyers, Cachupin and Vermejo River Canyons (Figure 4-13). The bed generally consists of two layers of coal, each two feet thick, separated by a carbonaceous shale 0.5 to 2 feet thick. Coal resources for the Ancho Canyon bed are an estimated 38.4 million tons (21.5 MT measured, 6.4 MT indicated, 10.5 MT inferred, with more than 25 million tons lying beneath less than 100 feet of overburden (Pillmore, 1969b).

4.2.1.2.7 York Canyon Coalbed

The York Canyon coalbed underlies an area of 12 square miles in York and Road Canyons (Figures 4-13 and 4-14). It varies from a bed containing many partings and only a few inches of coal in the southeastern part of the area, to a single coalbed more than 10 feet thick near York Canyon. A major parting rapidly thickens westward to 30 feet and divides the bed into upper and lower benches along the area's western margin. The York Canyon coalbed is 1,520 feet stratigraphically above the Trinidad Sandstone. Measured coal resources in the York Canyon area total 33.4 million tons in beds at least 4 feet thick (Pillmore, 1969b).

4.2.1.2.8 Chimney Divide Coalbed

The Chimney Divide coalbed outcrops through an area of 50 square miles and commonly consists of two benches, each 2 feet thick, separated by a carbonaceous shale parting from 6 inches to 1 foot thick (Figure 4-13). In some areas it may consist of a series of lenses at approximately the same stratigraphic position rather than a single continuous bed. Dense ground cover prevented accurate mapping of the coalbed. North of the Canadian River the coal becomes dirty, and splits into many layers of dirty coal and shale. Resources are estimated to be 97.5 million tons (48.3 MT measured, 29.3 MT indicated, 19.9 MT inferred) in beds at least 28 inches thick (Pillmore, 1969b). An estimated 22 million tons of the resources are in beds at least 42 inches thick.

4.2.2 Trinidad and Walsenburg Coal Fields

The U.S. Geological Survey estimated that the original in-place coal reserve of the Raton Mesa region totaled 2,304.2 million short tons. T.K. Matson of the U.S. Department of Energy estimated the original demonstrated reserve base to total 1,171.7 million short tons. Boreck and Murray (1979) report that the remaining reserves of the Trinidad and Walsenburg Coalfields as of 1977 were 671.47 million short tons. Measured sections of coalbeds in the Trinidad and Walsenburg Coal Fields are presented in Figures 4-16 through 4-23. A base map of the Trinidad and Walsenburg Coal Fields with the location of the measured sections is presented in Figure 4-15. Table 4-2 summarizes the ranges of typical analyses of coalbeds in the Trinidad and Walsenburg Coal Fields. Estimated resources for the coalbed are presented in Tables 4-3 through 4-5.

4.2.2.1 Vermejo Formation

The Vermejo contains three to 14 coalbeds greater than 14 inches thick everywhere in the Trinidad and Walsenburg Coal Fields. These coalbeds are lenticular, and irregular in thickness. Roof and floor rocks of coalbeds in the Vermejo Formation are usually carbonaceous shale and claystone, but locally may be carbonaceous siltstone or sandstone. Bony coal and shale form partings in the coalbeds (Johnson, 1961). The coal generally is of the same character as the Vermejo Formation coalbeds in the Raton Coal Field--brittle, friable with bright luster, and prismatic or cubic cleavage. Some of the coalbeds yield spherical bodies of coal up to 2 feet in diameter, evidently caused by squeezing within the beds.

4.2.2.1.1 Cameron, Lower Bunker Coal Zone

Coalbeds mined from this zone include the Cameron, Lower Alamo, Lower Bunker, Lower Piedmont, Maitland, and the Rouse. In the Walsenburg Field the only bed in this zone with significant reserves is the Cameron. It averages approximately 3 feet in thickness and ranges from 2 feet to a maximum of 5.75 feet with virtually no partings. The Cameron is usually less than 500 feet stratigraphically above the base of the Vermejo Formation.

The Lower Bunker Hill coalbed has also been mined in the Walsenburg Field but does not contain significant reserves. This bed is usually less than 2 feet thick, and has been naturally coked by igneous intrusions in the southern half of the field. Locally it is dirty and may contain partings of bony coal or shale.

In the Trinidad Coal Field, the Lower Piedmont coalbed is the only bed of this zone having significant reserves. In this field, the Lower Piedmont underlies 12 square miles along the Purgatoire River, averages 2.5 feet in thickness, ranges from 1 to 3.5 feet and is generally free of partings.

4.2.2.1.2 Berwind, Upper Bunker Coal Zone

Three beds found in this zone contain significant reserves in both the Walsenburg and Trinidad Coal Fields. These beds, the Rainbow, the Upper Bunker Hill, and the Berwind, are very similar in occurrence, each averaging approximately 2.5 feet of coal with thicknesses ranging from a trace to more than 7 feet. Two of the beds have been intruded and coked, and each contains local deposits of dirty coal and bony partings. A fourth coalbed, the Morley, was mined by C.F.& I. at the Morley Mine 4 miles north of the Colorado-New Mexico state line near Interstate 25. The Morley Mine was closed in 1954.

4.2.2.1.3 Majestic, Mammoth, Piedmont, Starkville, Walsen Coal Zones

Two beds, the Lenox and the Walsen, underlie 30 square miles of the Walsenburg Field and comprise a significant coal reserve. The most continuous of the two, the Lenox, averages about 2.5 feet in thickness, and locally contains bony coal and shale partings.

In the Trinidad Field two coalbeds of this zone are present: the Piedmont and the Lower Starkville. The Piedmont is more extensive, and averages five feet of coal, usually with a single parting that averages 1 foot thick.

4.2.2.1.4 Empire, Lower and Upper Ludlow, Majestic, Pryor Coal Zones

The Pryor, Empire, and Majestic coalbeds underlie 80 square miles Of both the Walsenburg and Trinidad Coal Fields. The most extensive coalbed, the Pryor, averages 3 feet thick with some local occurrences of bony coal and shale partings. The Majestic, thickest of the three, averages 7 feet and has been coked by intrusions along its southern extension. The Empire coalbed has an average aggregate thickness of 2 feet near the middle of the coal zone. The Empire has also been intruded, which destroyed most of the coalbed's northern portion. The Lower and Upper Ludlow coalbeds underlie an area of 10 square miles 15 miles northwest of Trinidad. These coalbeds are not very extensive and locally have been intruded and coked. The Upper and Lower Ludlow coalbeds have an average thickness of 5 feet.

4.2.2.1.5 Hastings and Robinson Coal Zone

The Lower Robinson coalbed in the Walsenburg Field is the most extensive of coalbeds in this zone. It averages 2.5 feet in thickness and is a relatively clean coal, i.e., no shale partings, bony coal, or natural coke. The less extensive, but thicker Hastings coalbed is found in the Trinidad Coal Field south of the town of Aquilar. Here the coalbed averages 6 feet thick with a maximum of 8 feet of coal. The southern portion of the coalbed has been coked by igneous intrusion.

4.2.2.1.6 Cokedale, Kebler, Occidental, Rapson, Thompson Coal Zone

The Rapson coalbed, with minable reserves in both the Walsenburg and Trinidad Coal Fields, is not very extensive and contains local zones of dirty or bony coal. It averages 2.5 feet in total thickness with at least one shale parting that may be as thick as 3 feet. The Upper Robinson coalbed of the Walsenburg Field is discontinuous in nature, and is truncated by an erosional unconformity at its northern limit. The Upper Robinson averages about 4 feet of coal in aggregate thickness, and normally has a shale parting 6 inches thick near its base. The Cokedale coalbed, with reserves in the Trinidad Field, has an average thickness of approximately 2 feet, and thins to the north and south, where its average thickness drops to about 1 foot.

4.2.2.1.7 Gem and Supris Coal Zone

The Gem coalbed mined in both the Trinidad and Walsenburg Coal Fields is a small bed of minimal extent. It averages 2.5 feet in thickness, and is found at relatively shallow depths. The Supris coalbed of the Trinidad Coal Field is a discontinuous deposit averaging 4 feet in thickness. It has been coked in the western portion of the deposit by igneous intrusives.

4.2.2.1.8 Apache Coalbed

The newly designated Apache coalbed of the Vermejo Formation is presently mined at the recently opened Maxwell Mine 3 miles southeast of Stonewall, Colorado. The Apache coalbed has an average thickness of 5 feet, and is overlain by 410 to 1,400 feet of overburden. Bituminous coal from the Maxwell Mine is used for coke -at the C.F.& I. steel mill in Pueblo, Colorado. Owned and operated by the C.F.& I. Steel Corporation, the Maxwell Mine will eventually phase out the Allen Mine, and has a planned production of 2,000 tons per day.

4.2.2.2 Raton Formation

Coalbeds of the Raton Formation are generally thinner, more lenticular, irregular in thickness, and more widely spaced than coalbeds of the Vermejo Formation. The coal is brittle and friable with a bright to dull luster, and has cubic or prismatic cleats and platy cleavage. At some locations, conchoidal fractures and spheroidal coal are common. A few coalbeds along the Purgatoire River have been destroyed by the intrusion of igneous sills. Roof and floor rocks are generally carbonaceous shale and siltstone; however, at many places the roof is a thick sandstone bed (Johnson, 1961).

4.2.2.2.1 Alfreda, Bear Canyon, Cass, Frederick Coal Zone

The lowermost zone of the Raton Formation in Colorado consists of several coalbeds ranging from a trace to greater than 10 feet in thickness. As previously stated, these beds are lenticular and have not been correlated the length of the Trinidad and Walsenburg Coal Fields. The Frederick bed is the thickest and most continuous of coalbeds in this zone. It averages 4 feet in aggregate thickness, with one or more partings of shale and siltstone averaging 18 inches total thickness. The Frederick was mined extensively along the Purgatoire River in the Trinidad Coal Field. Other coalbeds of this zone include: the Upper Rugby coalbed averaging 2.5 feet of coal split by a 6-inch shale parting; the Lower Rugby coalbed averaging 4 feet of coal with local zones of dirty or bony coal; the Alfreda coalbed averaging 2.5 feet of coal; the Cass coalbed averaging 3.5 feet of coal with one or more shale partings from 2 to 8 inches thick near the top of the bed; and the extensive Bear Canyon coalbed which averages 2 feet of coal and is characterized by several thin shale partings. All of the above beds, in addition to the Brodhead Number 4, the Martinez, the Primrose Number 2, the Rugby Number 3, and the Upper Series Number 3 coalbeds, occur within an interval of 150 feet located about 350 feet above the base of the Raton Formation.

4.2.2.2.2 Delagua and Peacock Coal Zone

This zone is composed primarily of the Delagua coalbeds mined along the eastern margin of the basin. Here the Delagua Number 1 coalbed ranges from 1.5 feet to 6 feet in thickness. In its northern and southern extremities, the coalbed is split by a shale parting up to 32 feet thick. This bed has been correlated for a lateral distance of about 15 miles. It lies 700 feet above the base of the Raton Formation.

4.2.2.2.3 Primer0 Coal Zone

The Primero coalbed of this zone has been mined along the Purgatoire River in the Trinidad Coal Field. Along with the Frederick coalbed, it underlies as much as 75 square miles in the above-mentioned area. It ranges in thickness from a few inches to greater than 6 feet, and averages approximately 3 feet. The Allen coalbed of this zone is presently mined at the Allen Mine located along the Purgatoire River near the town of Stonewall. This bed averages 5 feet in thickness and is overlain by 100 to 2,500 feet of overburden. It is a high-volatile B bituminous coal used by the C.F.& I. Steel Corporation as a blending coal for the production of coke.

4.2.2.2.4 Boncarbo Coal Zone

The Boncarbo coalbed ranges in thickness from 5 to 7 feet, commonly with two or more partings composed of shale and sandstone with an aggregate thickness of 6 to 12 inches.

4.2.2.2.5 Ciruela Coalbed

The Ciruela coalbed, mined primarily along the Purgatoire River, appears to be quite lenticular, and locally may be absent. The Ciruela is not of great economic importance, but locally it appears sufficiently thick to have possible future value. It averages 1.5 feet thick and has a maximum thickness of up to 2.5 feet.

4.2.2.2.6 "A" and "B" Coalbeds

Along the eastern margin of the Walsenburg Coal Field, two coalbeds, termed the "A" and "B" coalbeds (Johnson, 1958), occur at or near the base of the Raton Formation. These beds have been correlated by measured coal sections at outcrops and by drill hole sections. The lower "A" coalbed, usually located within 5 feet of the base of the Raton Formation, is the more continuous of the two beds and averages 2.5 feet in thickness. Both beds pinch out 6 miles south of Walsenburg; the "B" coalbed pinches out about 9 miles north of Walsenburg.

4.3 STRUCTURAL CHARACTER

The structural character of coals of the Raton Mesa region, such as fracture or cleat density and orientation, has not been systematically investigated. Most coal in the region is fractured, either cubically or prismatically, and in some of the mines this cleating is so marked that coal can be readily removed from the working faces by picks (Lee, 1924). Coal that has been intruded and metamorphosed is columnarly jointed. The jointing is polygonal and is developed at right angles to the intrusive bodies.

Generalized isopach maps of the Trinidad sandstone, Vermejo, and Raton Formations are shown in Figures 4-24, 4-25 and 4-26. A generalized isopach map of coalbeds in the Vermejo Formation is shown in Figure 4-27. As noted in Section 4.1, the coalbeds crop out along the eastern margin of the coal fields and dip gently to the west. The coalbeds also are exposed along the major stream drainages, and in the vicinity of the Vermejo Park Anticline. The coalbeds are probably 3,000 to 4,000 feet deep at the basin axis near Spanish Peaks.

The only report of cleat direction in coalbeds was by Pillmore (1969). He recorded a well developed face cleat system oriented N70°W in an unnamed coalbed of the Vermejo Formation located throughout the Vermejo Park area. The axis of the Vermejo Park Anticline, North to N20°W, is essentially perpendicular to the face cleat direction.

The Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor is using LANDSAT imagery to predict roof conditions for underground metal, nonmetal, and coal mines. Trained observers of the Ground Support and Roof Control Branches of MSHA identify and plot geologic irregularities or linears indicative of fractures or fault systems which could result in roof failure. Kaiser Steel Corporation used the program to determine roof conditions of the York Canyon Mine. Results from this program have accurately predicted roof instability in several mines. Analysis of satellite imagery for the Raton Mesa region would be necessary in predicting methane drainage patterns. LANDSAT imagery for the Raton Mesa region is presented in Figure 4-28.

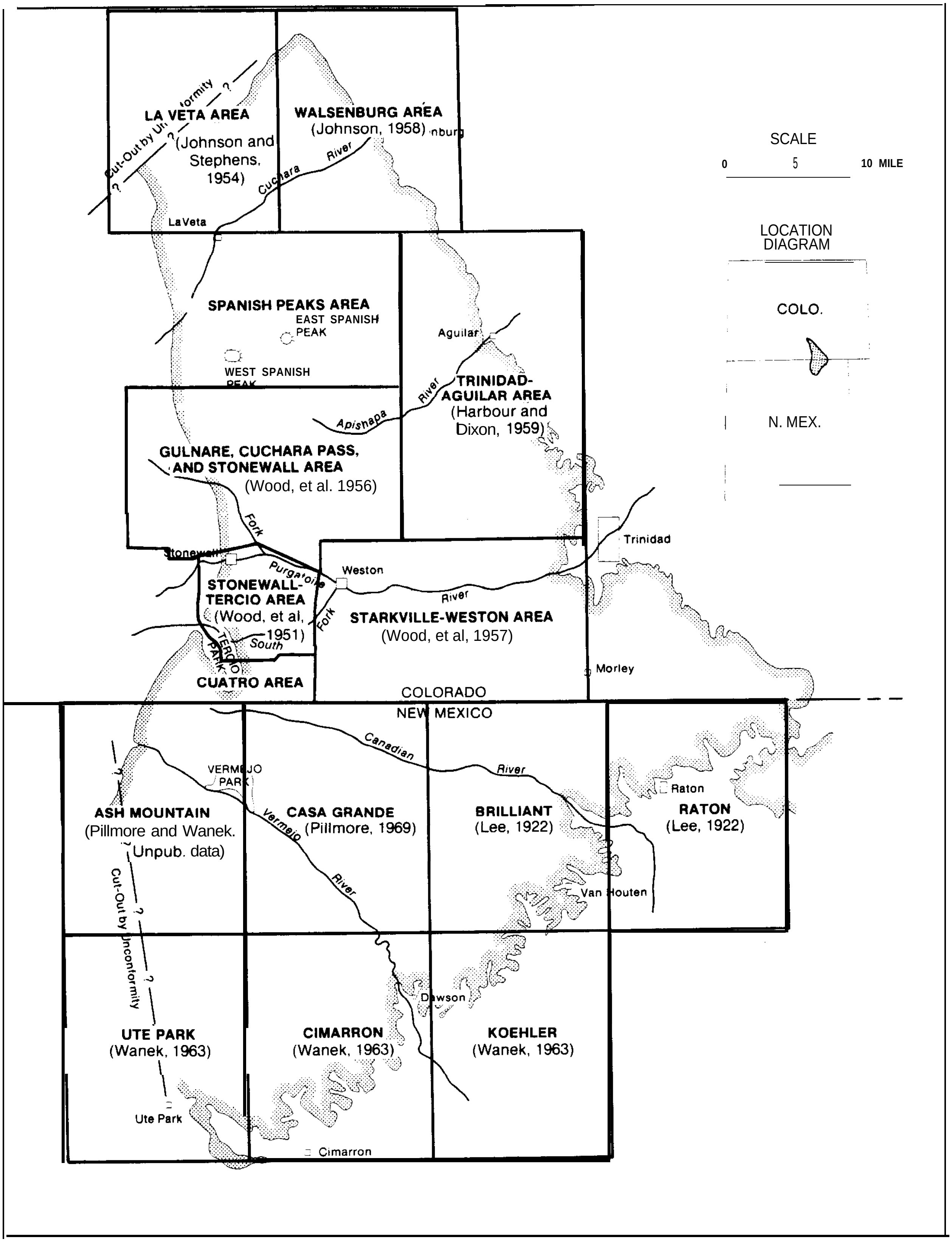


Figure 4-1 Index Map of the Raton Mesa Region Showing Areas of Geologic Reports by the Geological Survey (Johnson, 1961 and Pillmore, 1969)

AGE	ROCK UNITS, WITH APPROXIMATE THICKNESSES (IN FEET)			KNOWN COAL BEDS MINED
UPPER CRETACEOUS	RATON FORMATION			
	VERMEJO FORMATION 79 - 552	varies		
		± 40	Gem & Sopris Coal 'Zones' Varies	Forbes, Gem, Sopris, Sopris (Plaza). Valley Mine
		± 30	Cokedale. Kebler, Occidental. Rapson, Thompson, Upper Robinson Coal 'Zones' Varies	Cameron (?), Cokedale. Kebler (?) Occidental, Rapson. Robinson No. 2. 'Thompson, Upper Robinson
		± 20		
		± 30	Hastings & Robinson Coal 'Zones' Varies	Hastings, Hezron, Kebler No. 2, Robinson, Sopris
		± 50	COD, Empire. Lower & Upper Ludlow. Majestic, Middle Creek, Pryor Coal 'Zones' Varies	Bower, COD, Empire. Forbes (?) Lower Ludlow, Majestic, Middle Creek, Pryor, Tabasco, Upper Alamo, Upper Ludlow
		± 20	Majestic, Mammoth, Piedmont, Starkville. Walsen Coal 'Zones' Varies	Aguilar, El Moro. Engle-Starkville. Engleville. Lennox, Lower & Upper Starkville, Mammoth, New Rouse, Peerless, Piedmont, Walsen
		± 20	Berwind. Upper Bunker Coal 'Zones' Varies	Berwind. Cretaceous. Morley. Rainbow, Upper Bunker
		+ 20	Cameron, Lower Bunker Coal 'Zones' Varies	Cameron, Lower Alamo, Lower Bunker, Lower Piedmont, Maitland, Rouse
	TRINIDAD SANDSTONE			

No Vertical Scal

Figure 4-2. Generalized Columnar Section of Coal-Bearing Rocks in the Vermejo Formation, Raton Mesa Region, Colorado (Boreck and Murray, 1979)

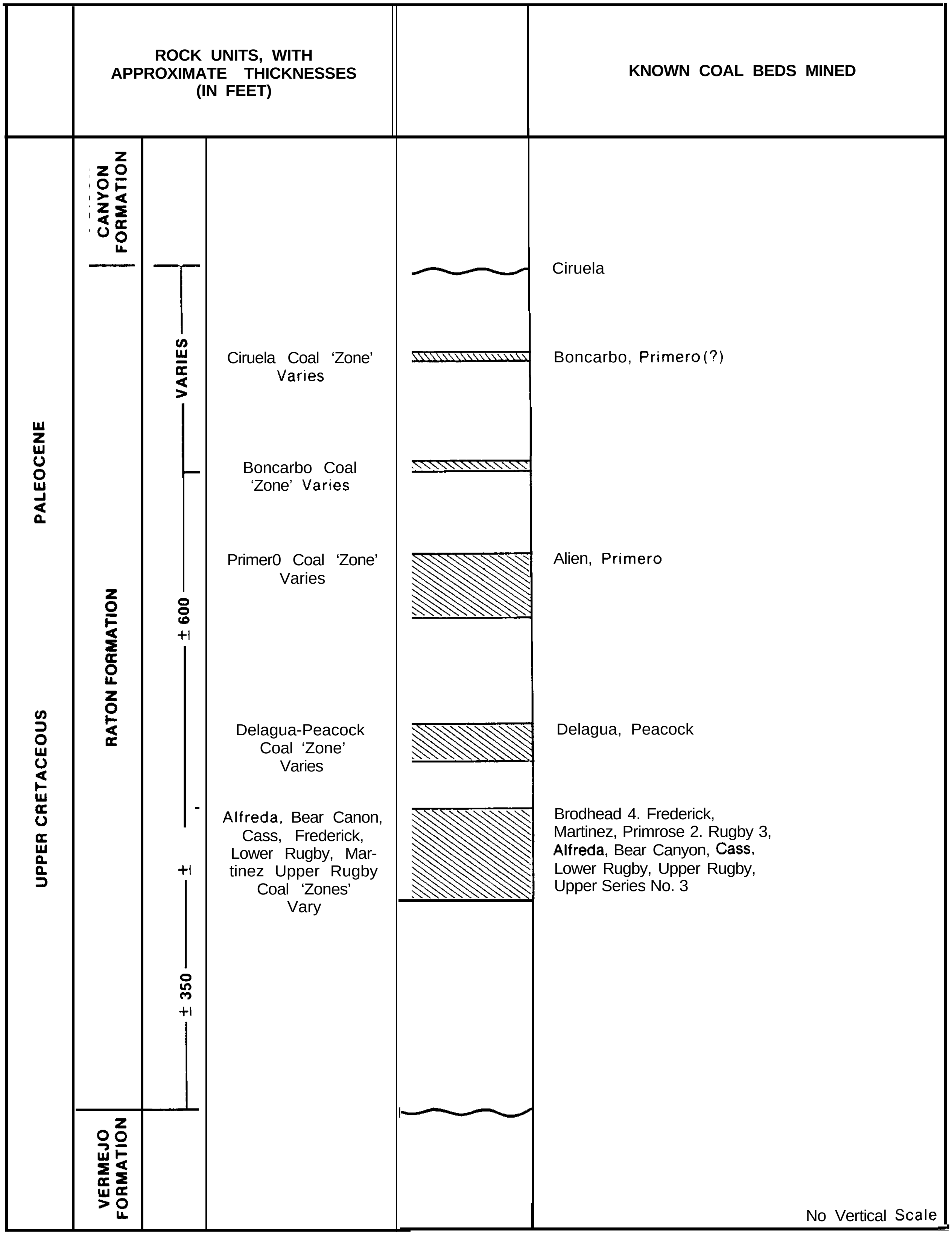


Figure 4-3. Generalized Columnar Section of Coal-Bearing Rocks in the Raton Mesa Region, Colorado (Boreck and Murray, 1979) (Courtesy of Colorado Geological Survey)

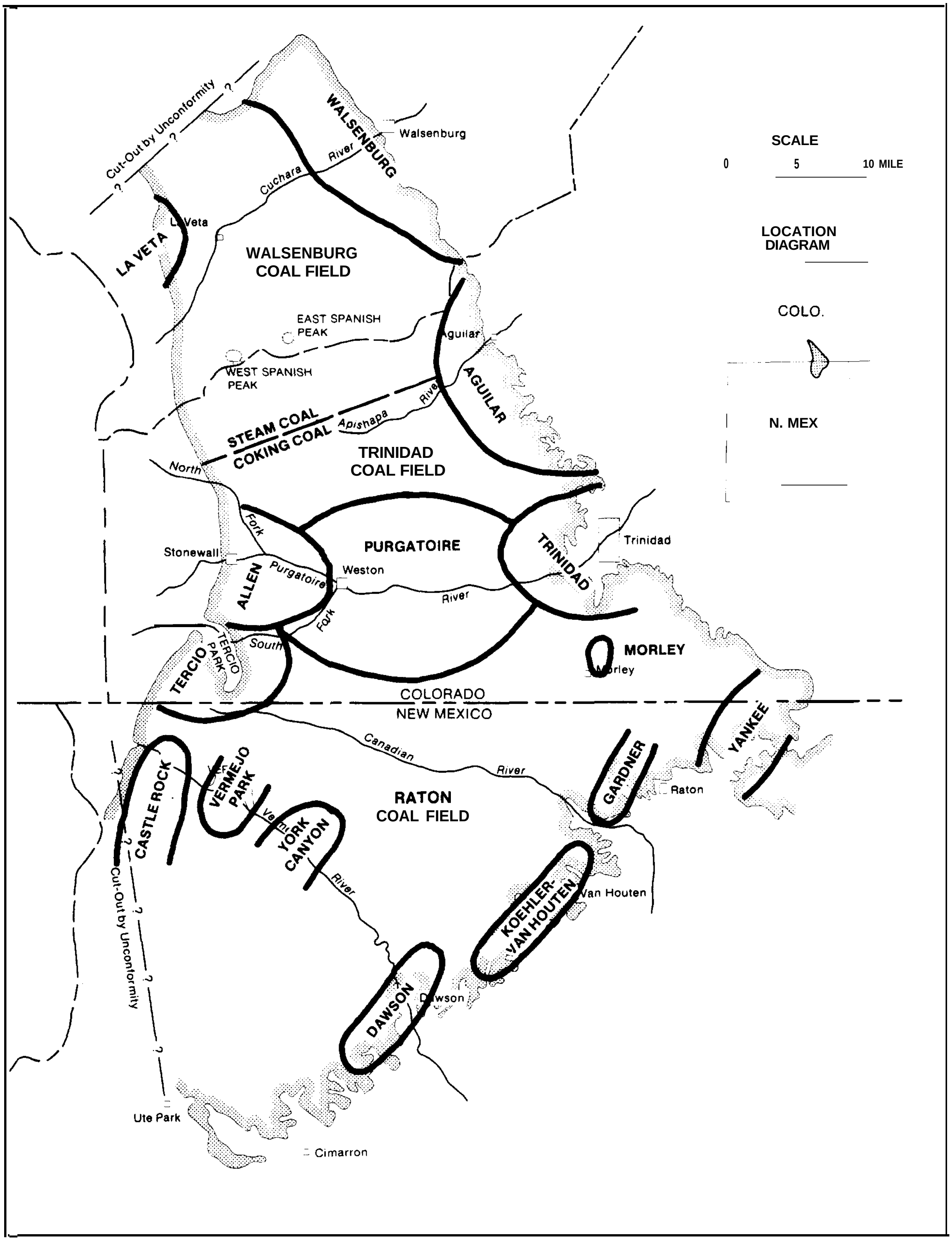


Figure 4-4. Mining Districts of the Raton Mesa Region (Amuedo and Bruson, 1977)
(Courtesy of Colorado Geological Survey)

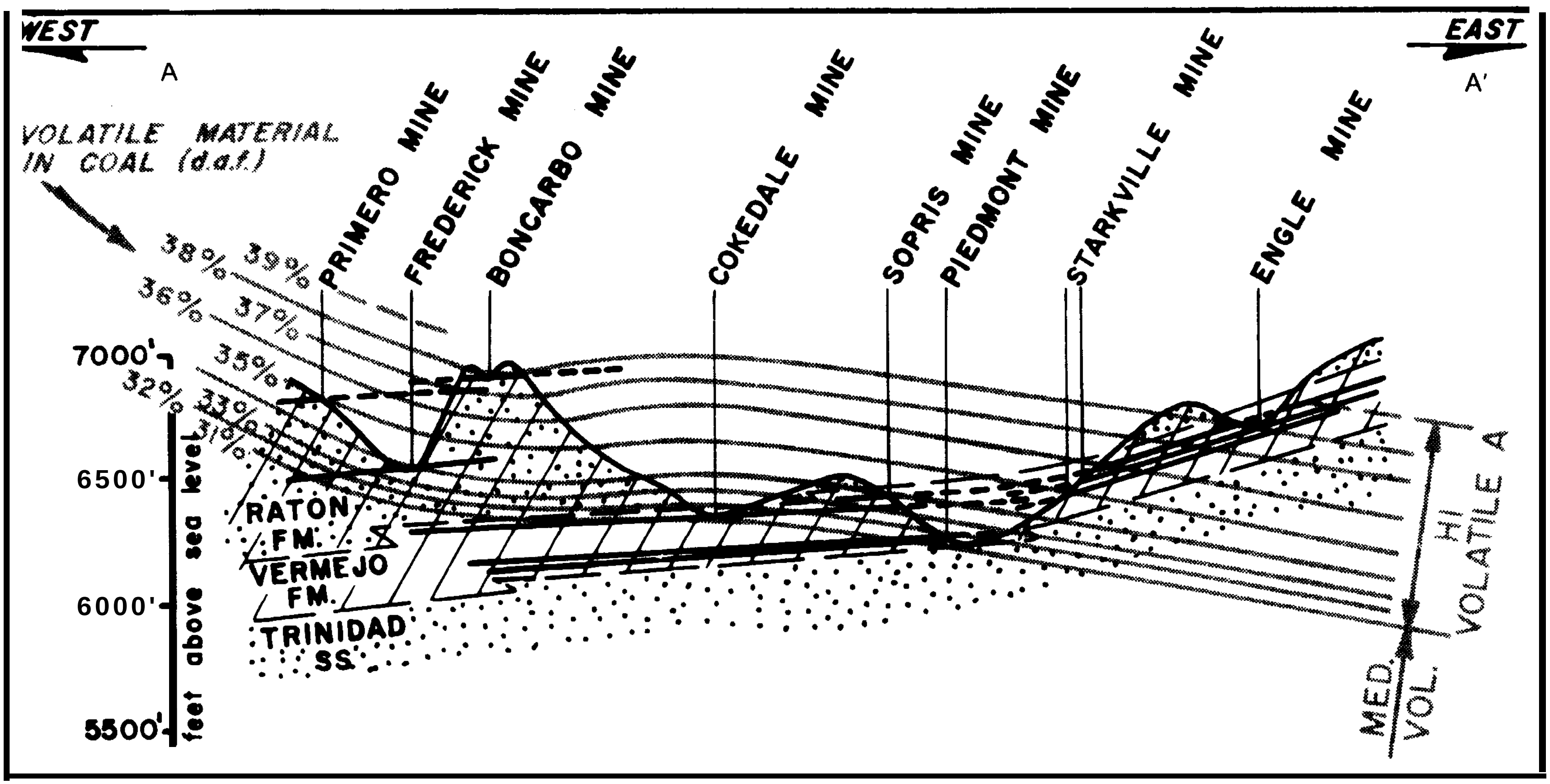


Figure 4-5. Cross Section Pattern of Coal Metamorphism Along the Purgatoire River. Reference Figure 4-I 5 (Courtesy of RMAG)

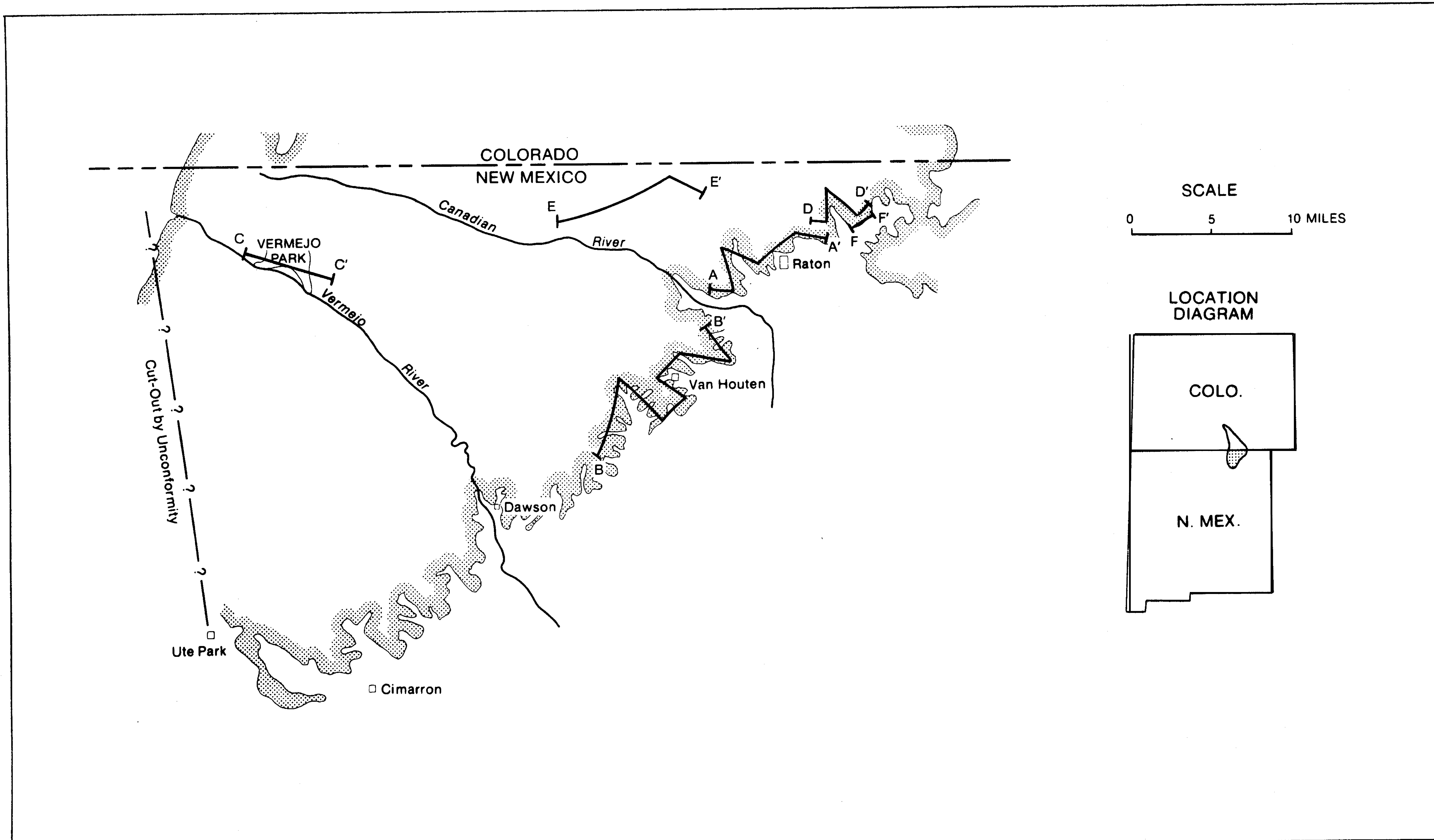


Figure 4-6. Base Map of the Raton Coal Field Showing the Location of Sections Depicted in Figures 4-7 Through 4-12

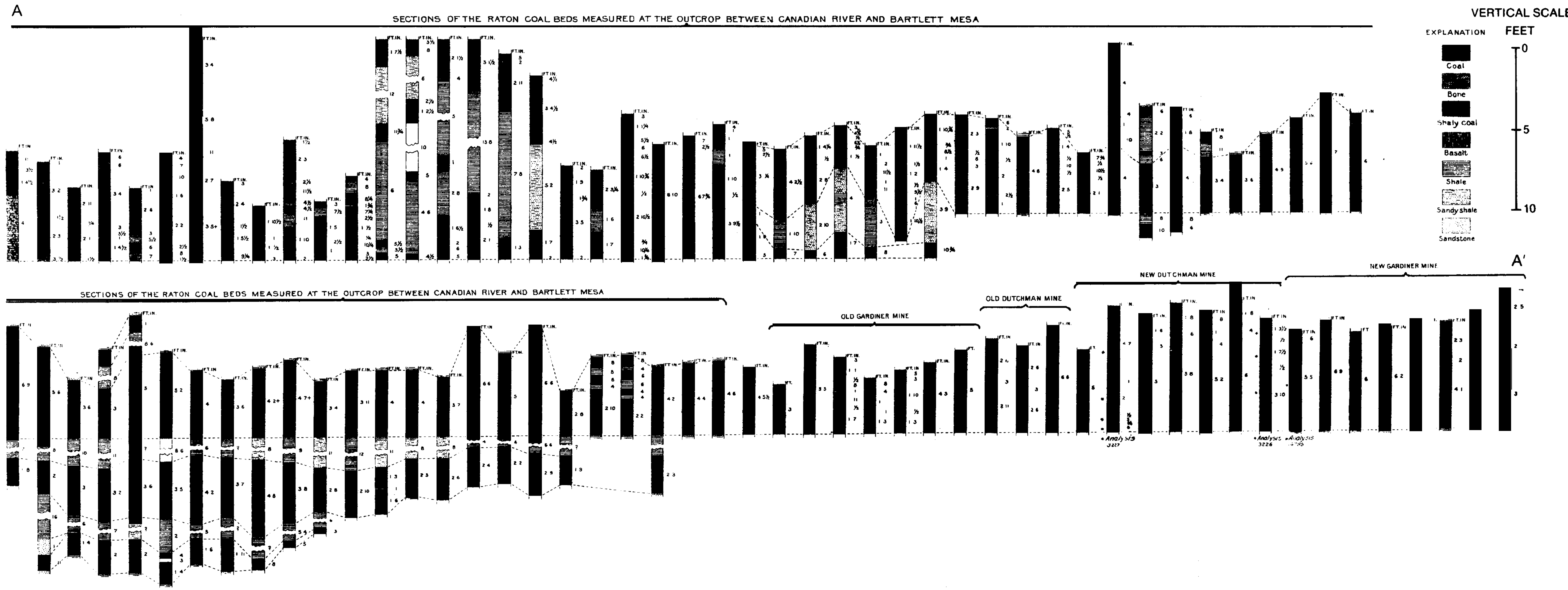


Figure 4-7. Sections of the Coalbeds in the Vermejo Formation Measured at the Outcrop and in Mines Between Canadian River and Raton, New Mexico. Reference Figure 4-6 (Lee, 1924)

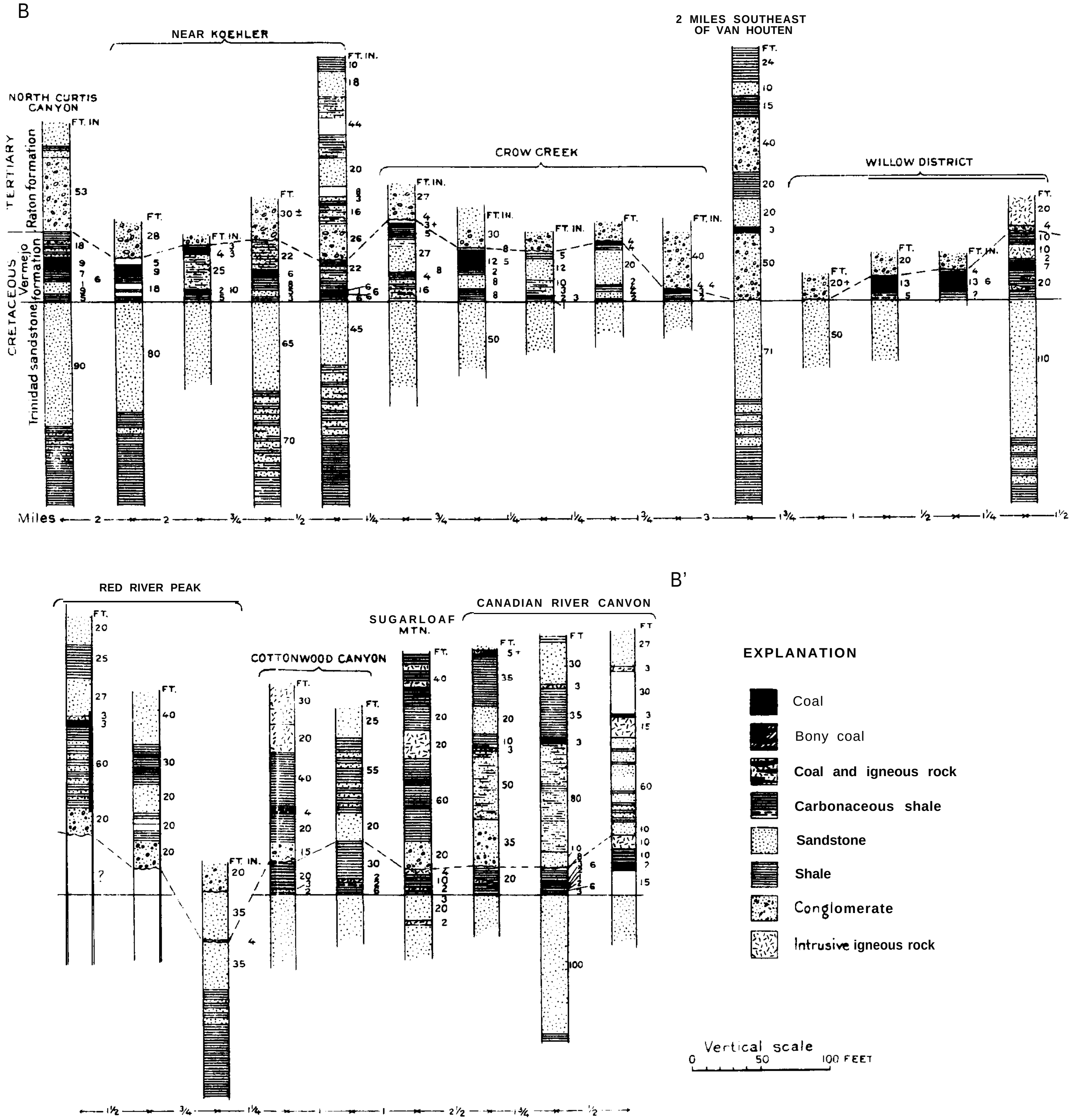


Figure 4-8. Sections Measured at the Outcrop of the Raton Coalbed Between Koehler and Sugarite, New Mexico. Reference Figure 4-6 (Lee, 1924)

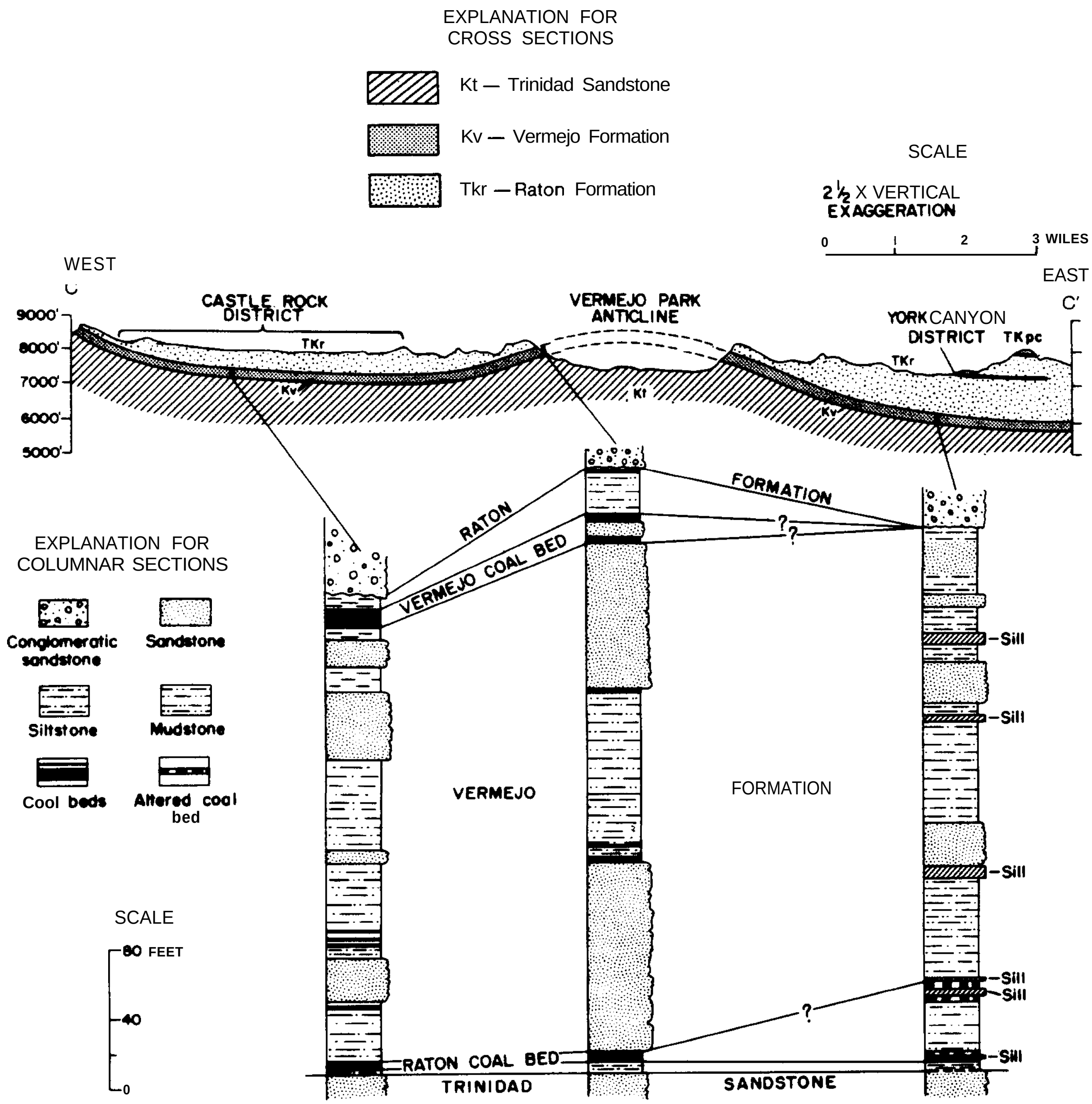


Figure 4-9. Cross Section and Columnar Sections Showing Vermejo Park Anticline and and Lithologic Changes in the Vermejo Formation Across the Northwestern Pat-t of the Raton Coal Field. Reference Figure 4-6 (Pillmore, 1969) (Courtesy of RMAG)

D

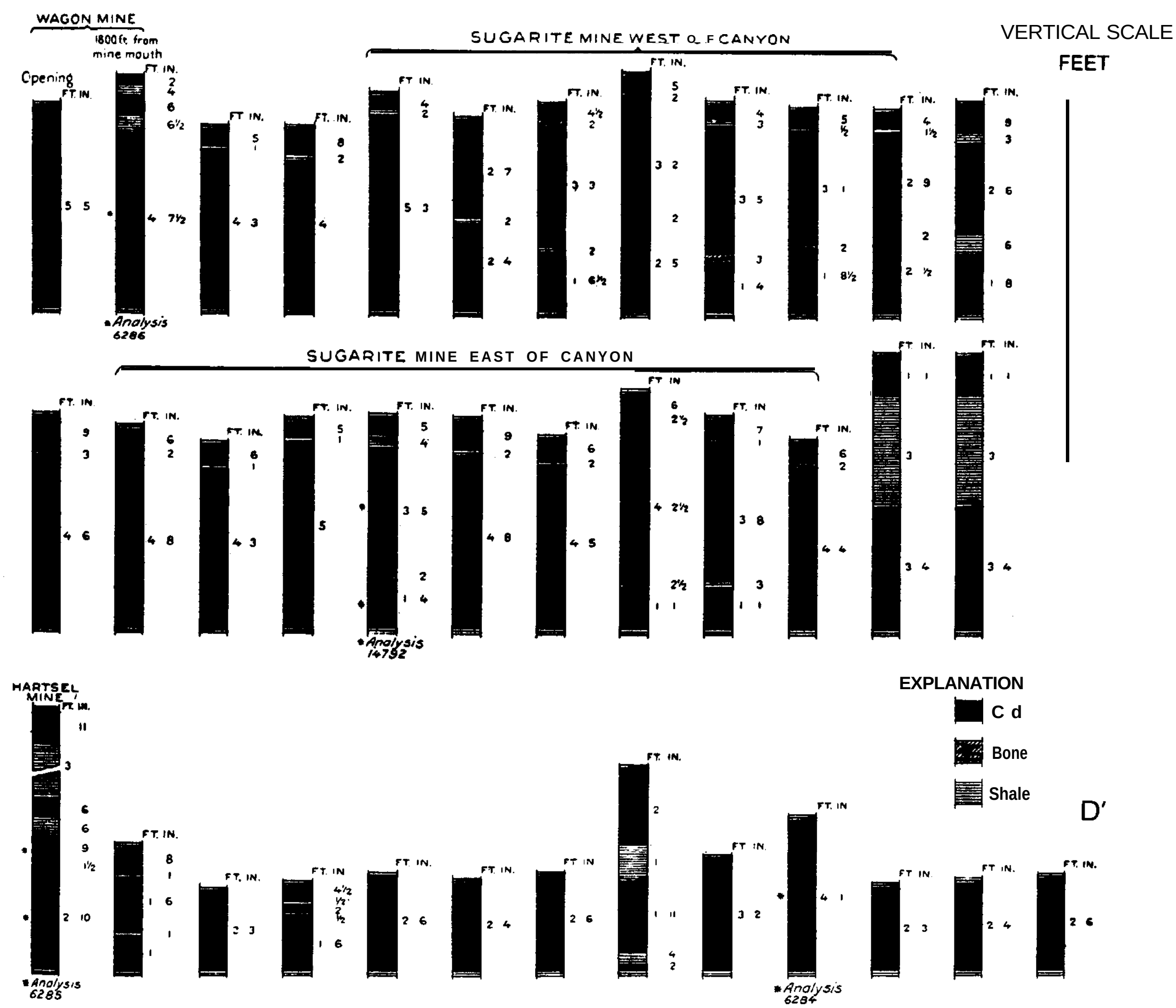


Figure 4-10. Sections of the Sugarite Coalbed. Reference Figure 4-6 (Lee, 1924)

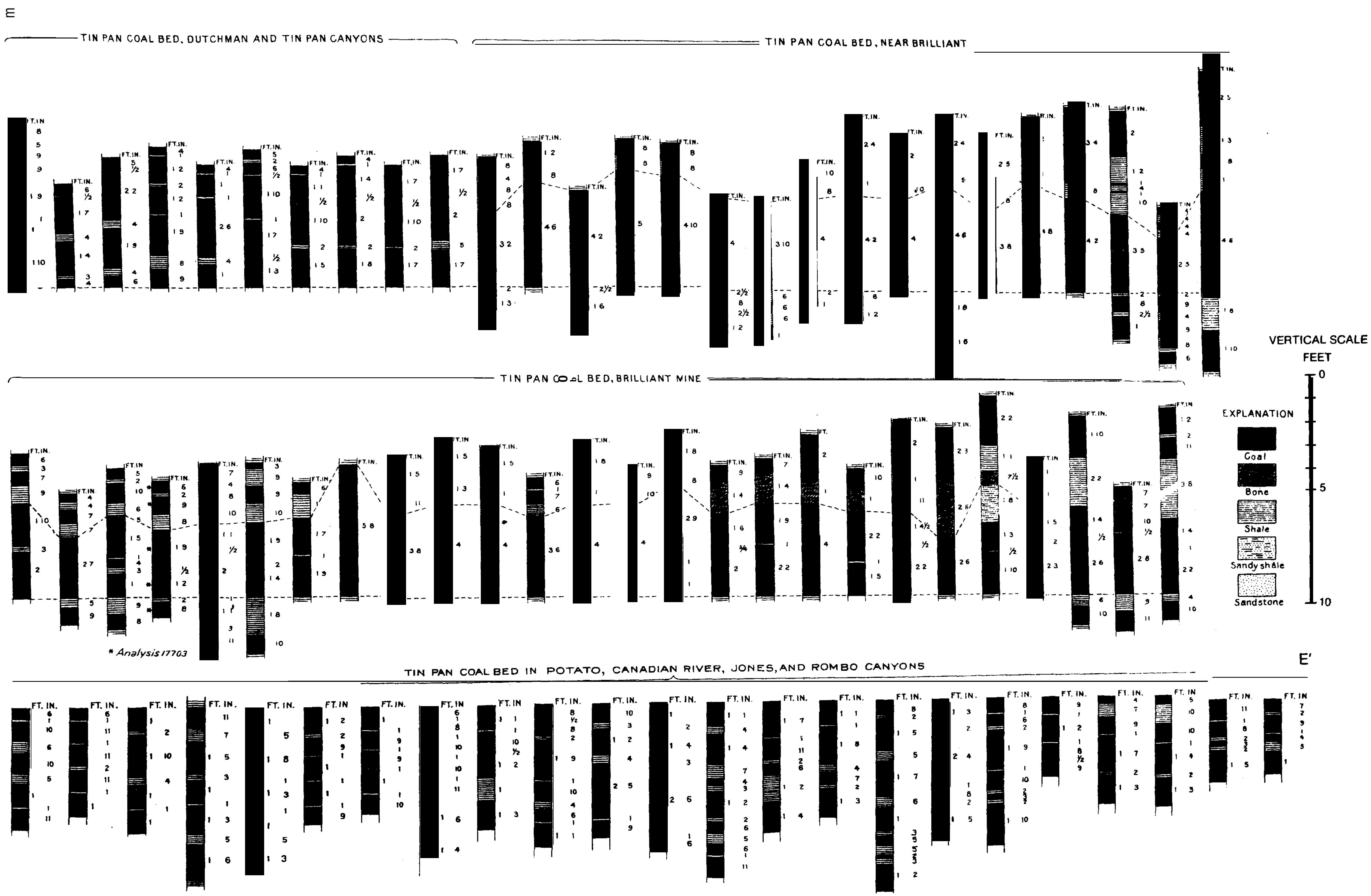


Figure 4-11. Measured Sections of the Tin Pan Coalbed. Reference Figure 4-6 (Lee, 1924)

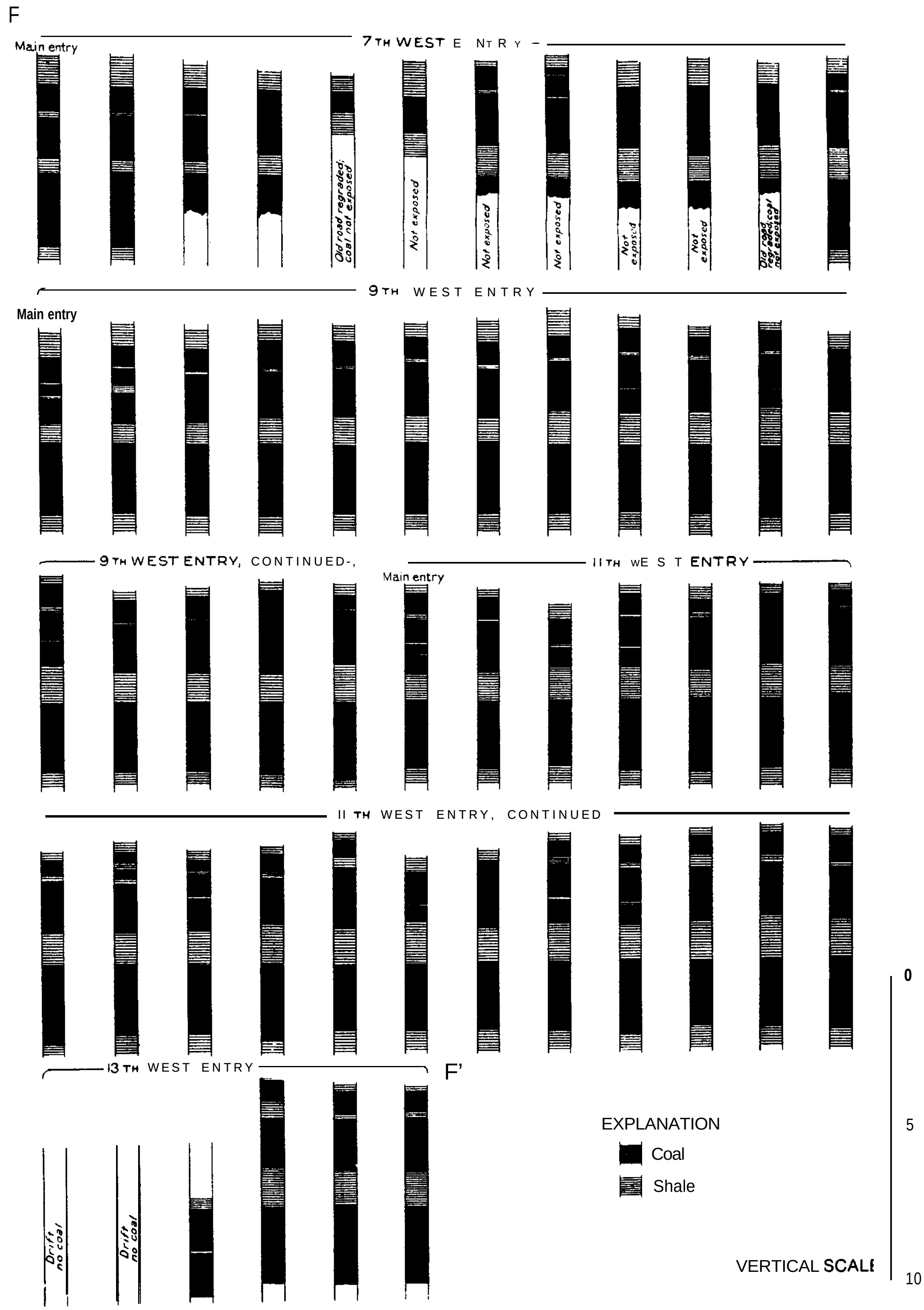


Figure 4-12. Measured Sections of the Yankee Coalbed at the Yankee Mine. Reference Figure 4-6 (Lee, 1924)

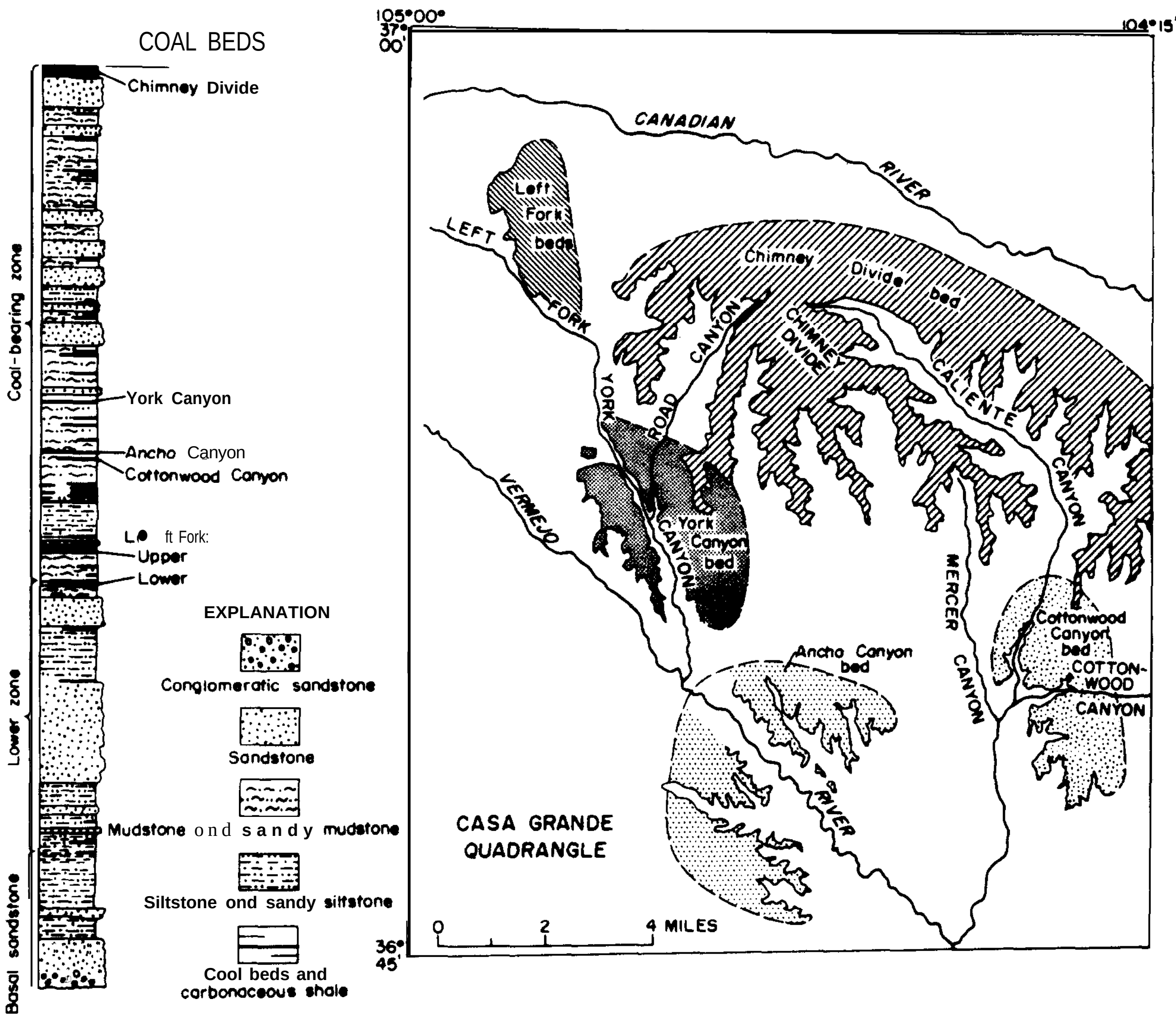
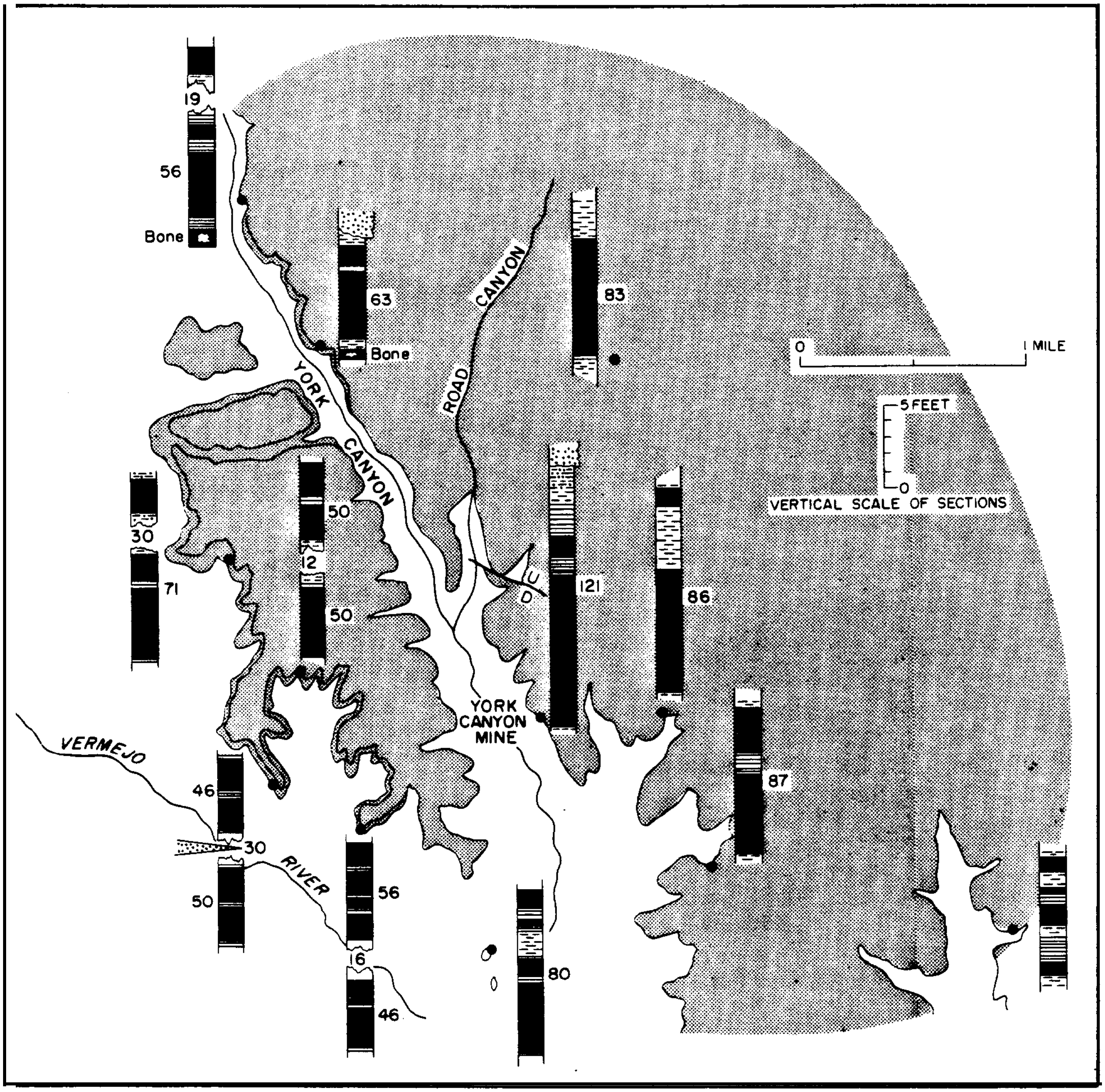


Figure 4-13. Stratigraphic Relations and Generalized Bed Map of Some of the Major Coalbeds in the Raton Formation in the Central Part of the Raton Coal Field, Showing Areas for Which Coal Resources Have Been Calculated (Pillmore, 1969) (Courtesy RMAG)



EXPLANATION

Area for which coal resources have been calculated

● Location of measured coal section

46 Coal thickness in inches

$\frac{U}{D}$ Fault Showing Relative Displacement

Figure 4-14. Coal Sections of the York Canyon Coalbed Near the Vermejo Anticline (Courtesy RMAG)

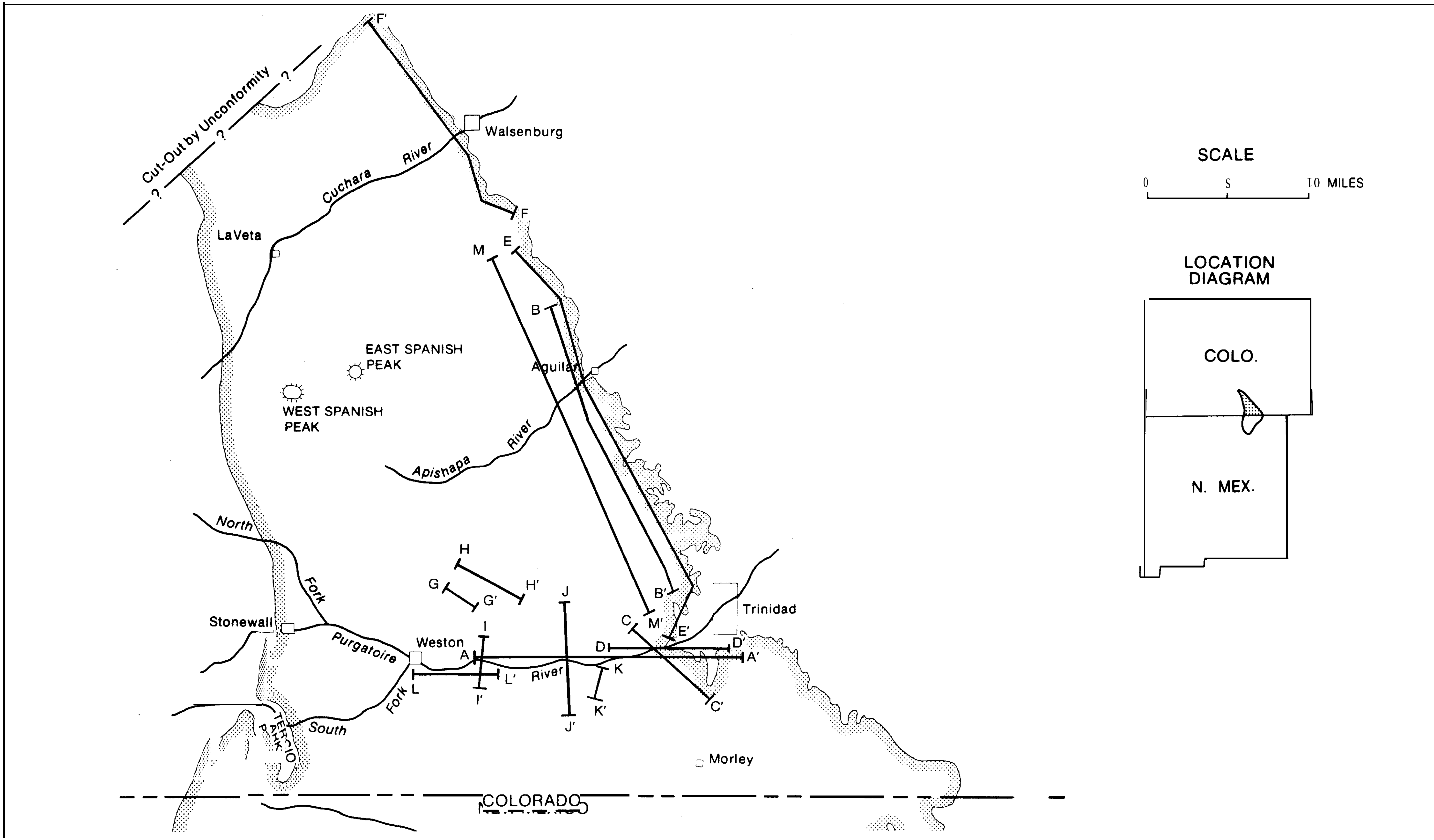


Figure 4-15. Base Map of the Trinidad and Walsenburg Coal Fields Showing the Location of Sections Depicted in Figures 4-16 Through 4-23.

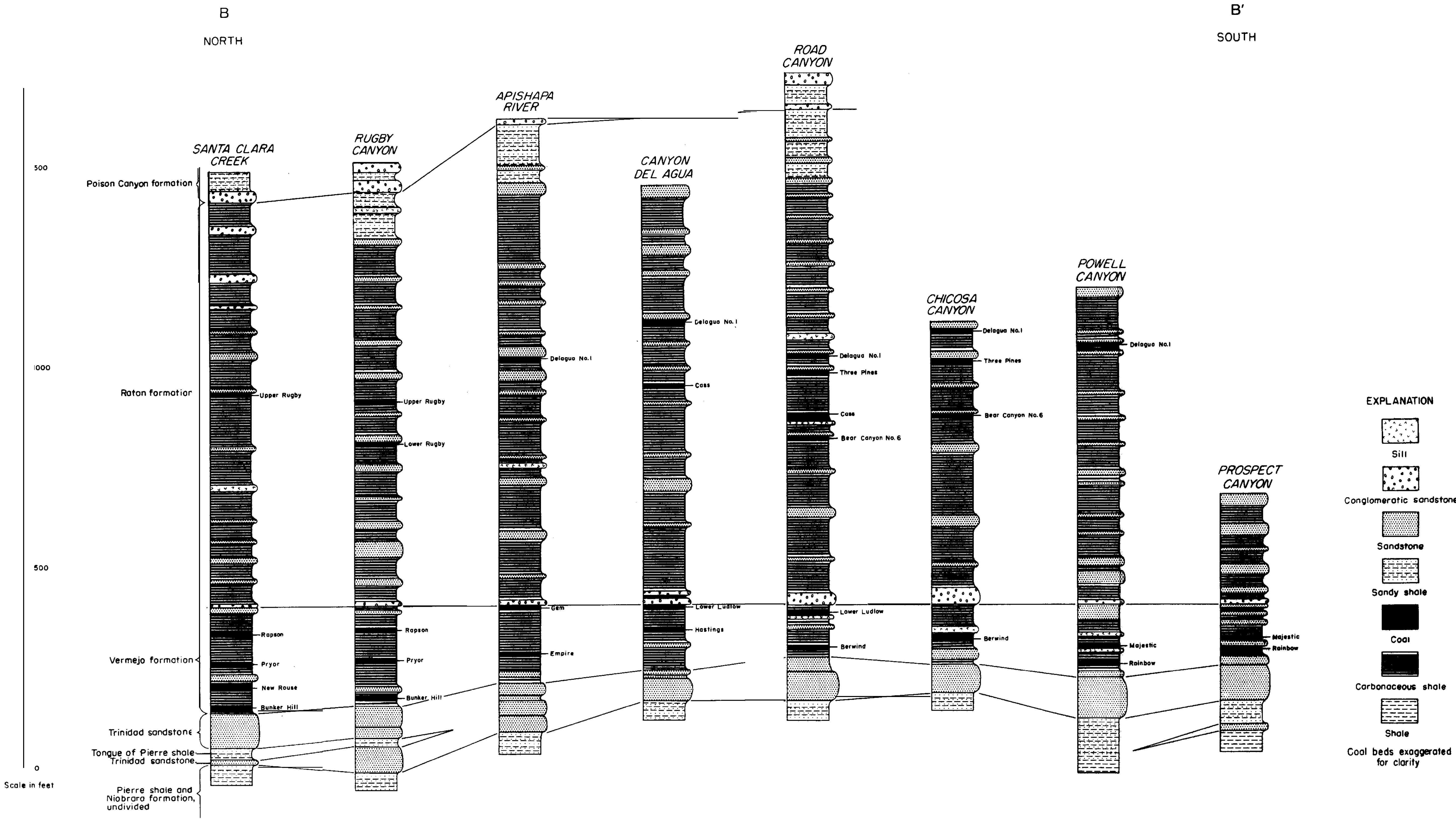


Figure 4-16. Generalized Stratigraphic Sections of the Trinidad, Vermejo, and Raton Formations. Reference Figure 4-15 (Harbour and Dixon, 1959)

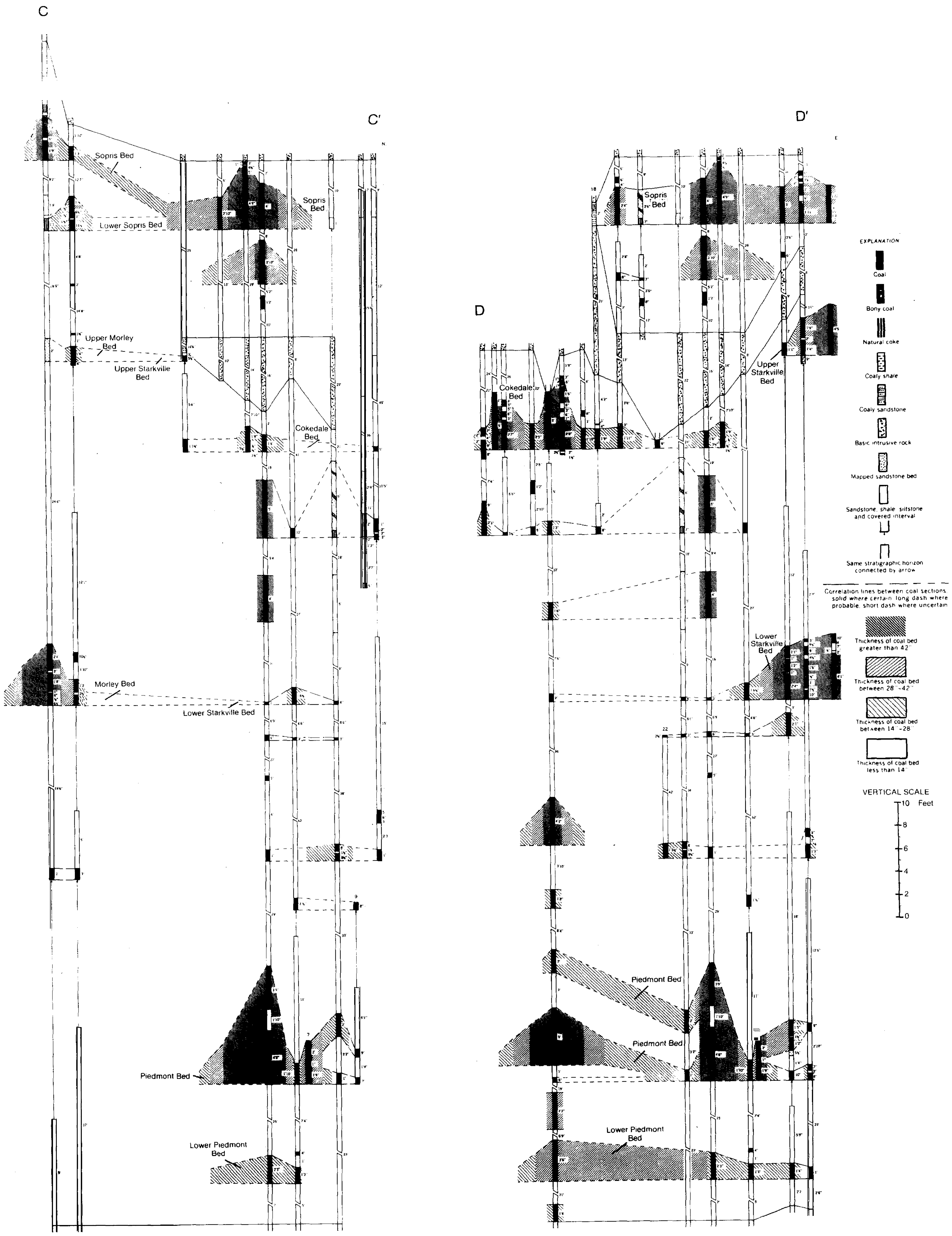


Figure 4-17. Sections of Coalbeds in the Vermejo Formation, Las Animas County, Colorado. Reference Figure 4-15 (Wood, et al, 1957)

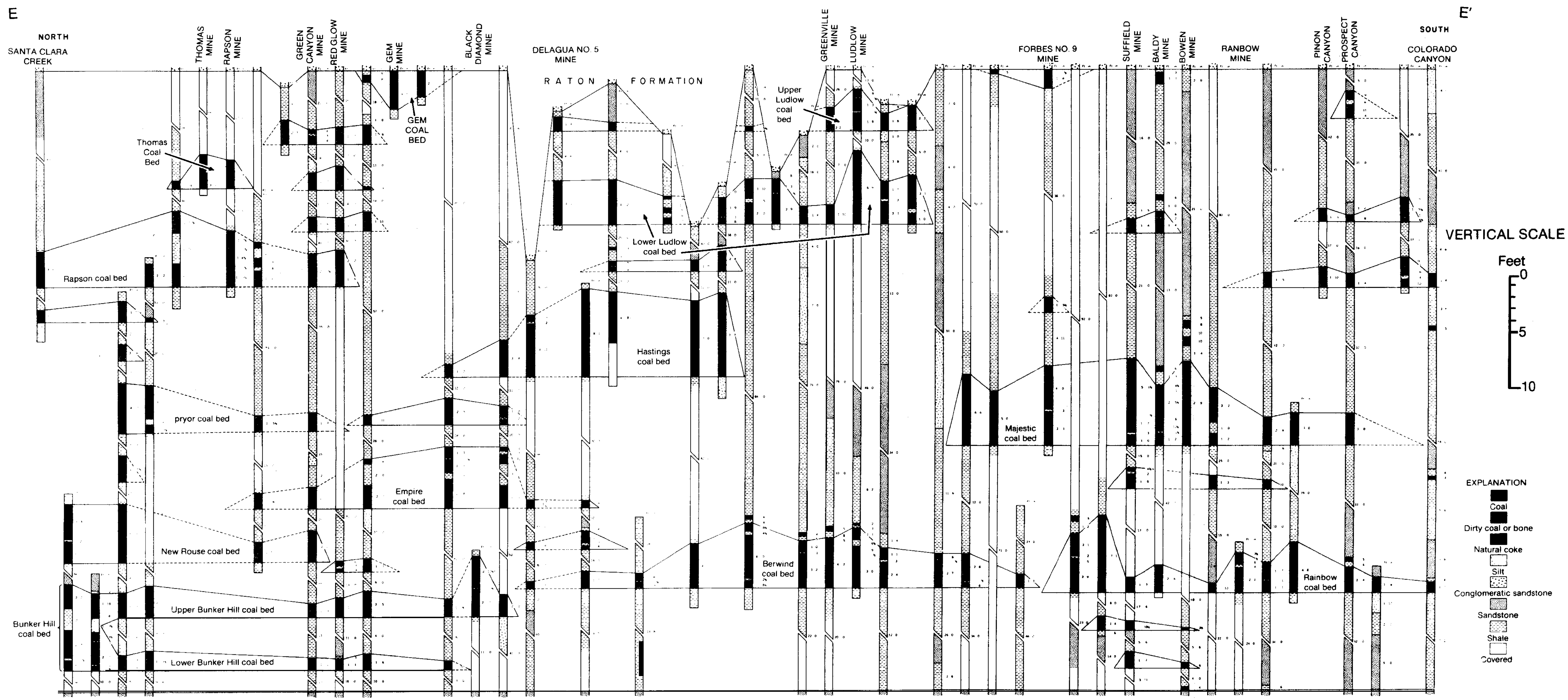
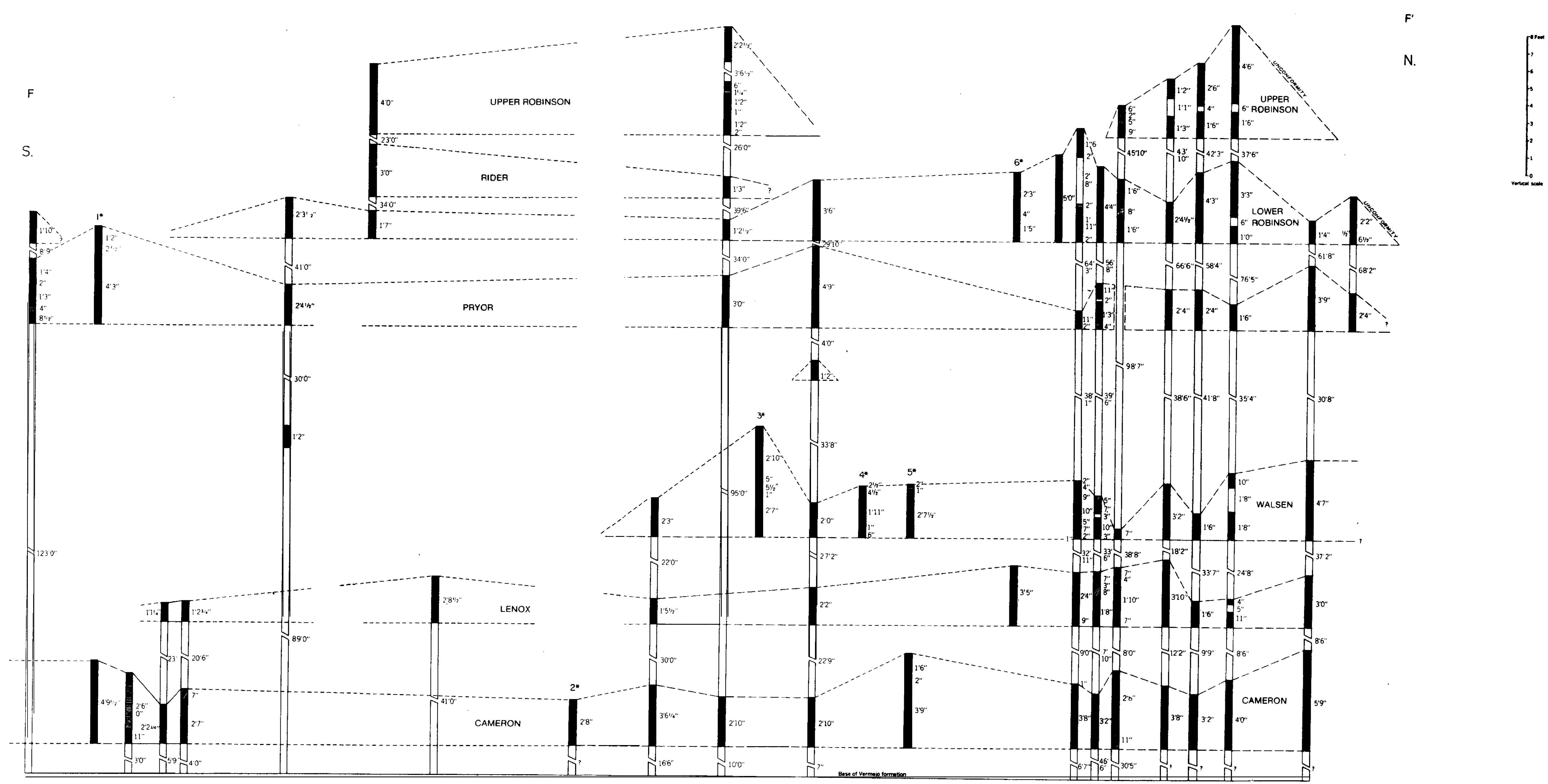


Figure 4-18. Sections of Coalbeds in the Vermejo Formation, Las Animas and Huerfano Counties, Colorado. Reference Figure 4-15 (Harbour and Dixon,1959)



1* Pryor mine—Face of 3 north entry and face of 2 south entry
2* Ravenwood mine—Face of 11 main north entry
3* Robinson No. 1 mine—Face of 1 room, 3 south entry, 9 north entry
4* Caddell No. 3 mine
5* Toltec mine—Face of 3 west entry
6* Maitland mine—Face of dip entry and face of 9 room, 1 north entry

Figure 4-19. Sections of Coalbeds in the Vermejo Formation, Huerfano County, Colorado. Reference Figure 4-15 (Johnson, 1950)

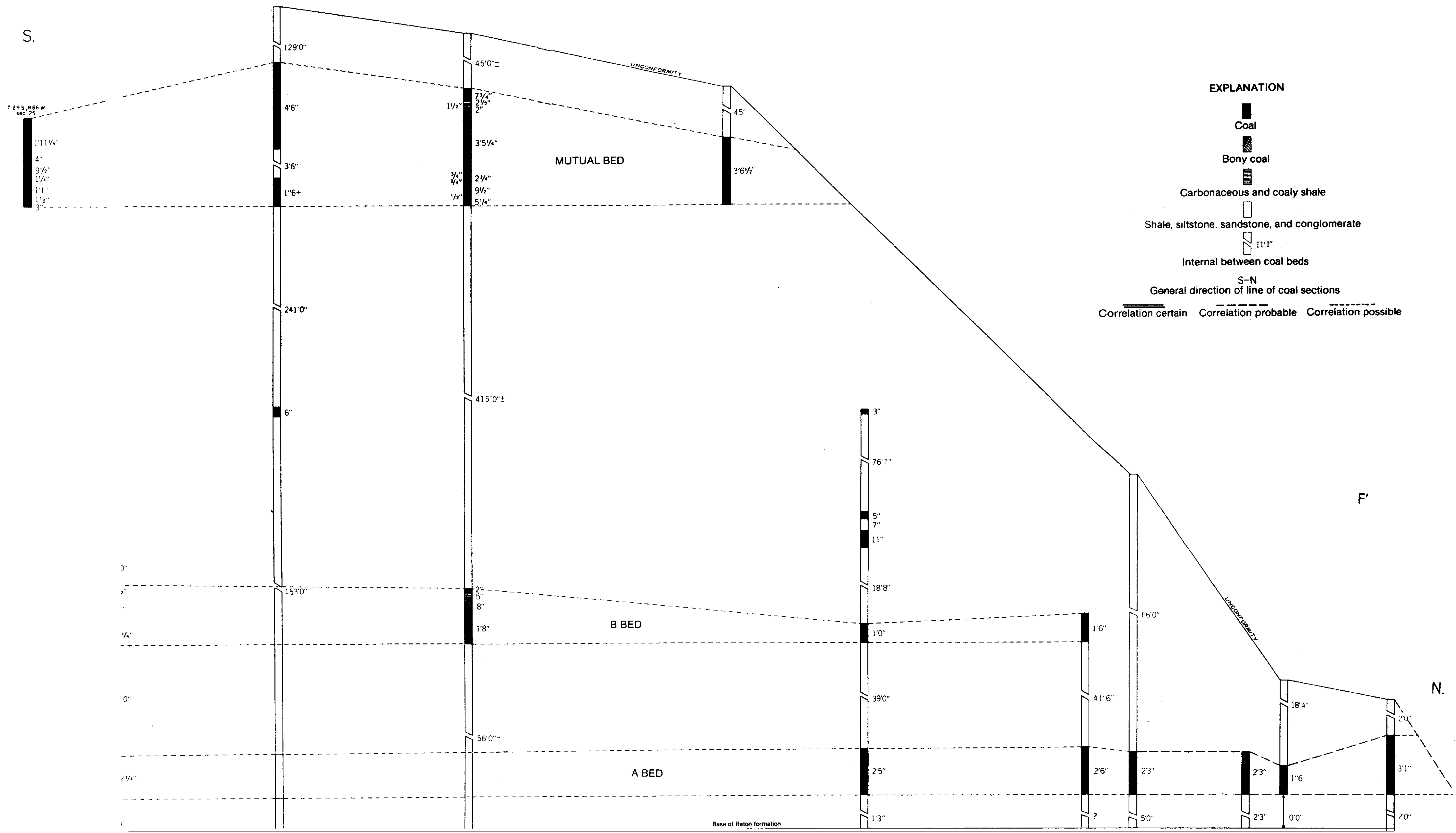


Figure 4-20. Sections of the Coalbeds in the Raton Formation, Huerfano County, Colorado. Reference Figure 4-15 (Johnson, 1958)

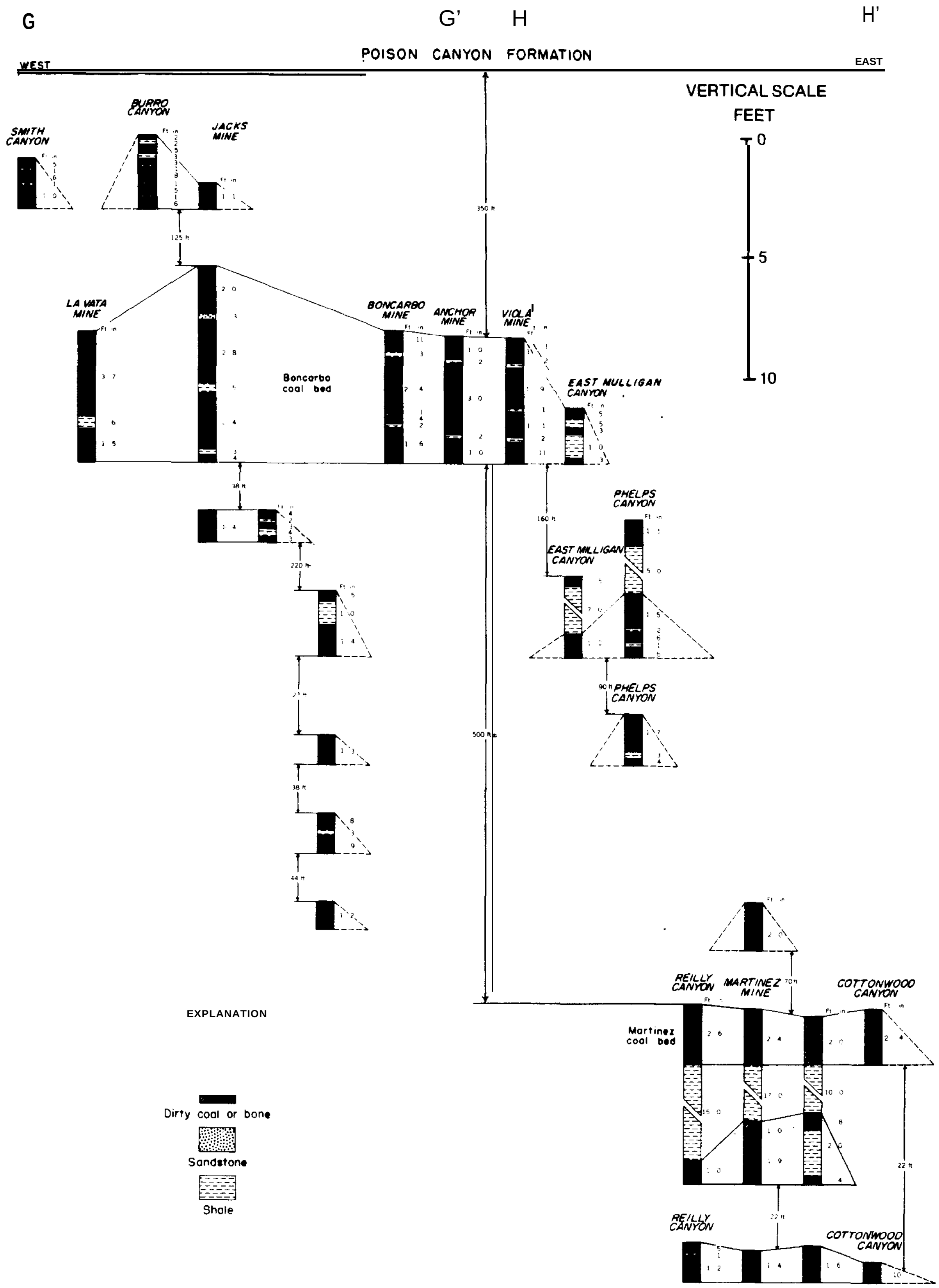


Figure 4-21. Sections of Coalbeds in the Raton Formation from Smith Canyon to Cottonwood Canyon, Las Animas County, Colorado. Reference Figure 4-15 (Harbour and Dixon, 1959)

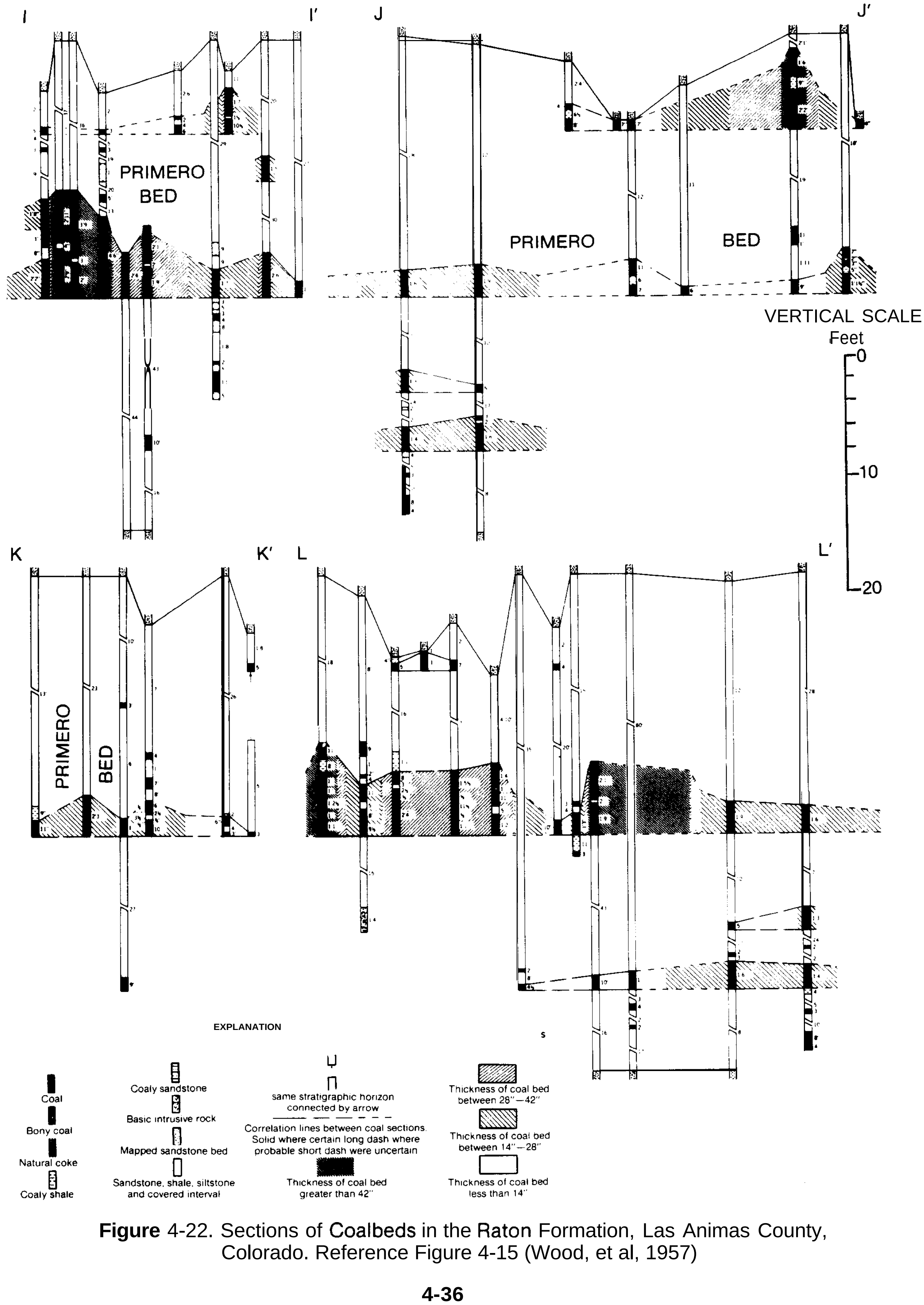


Figure 4-22. Sections of Coalbeds in the Raton Formation, Las Animas County, Colorado. Reference Figure 4-15 (Wood, et al, 1957)

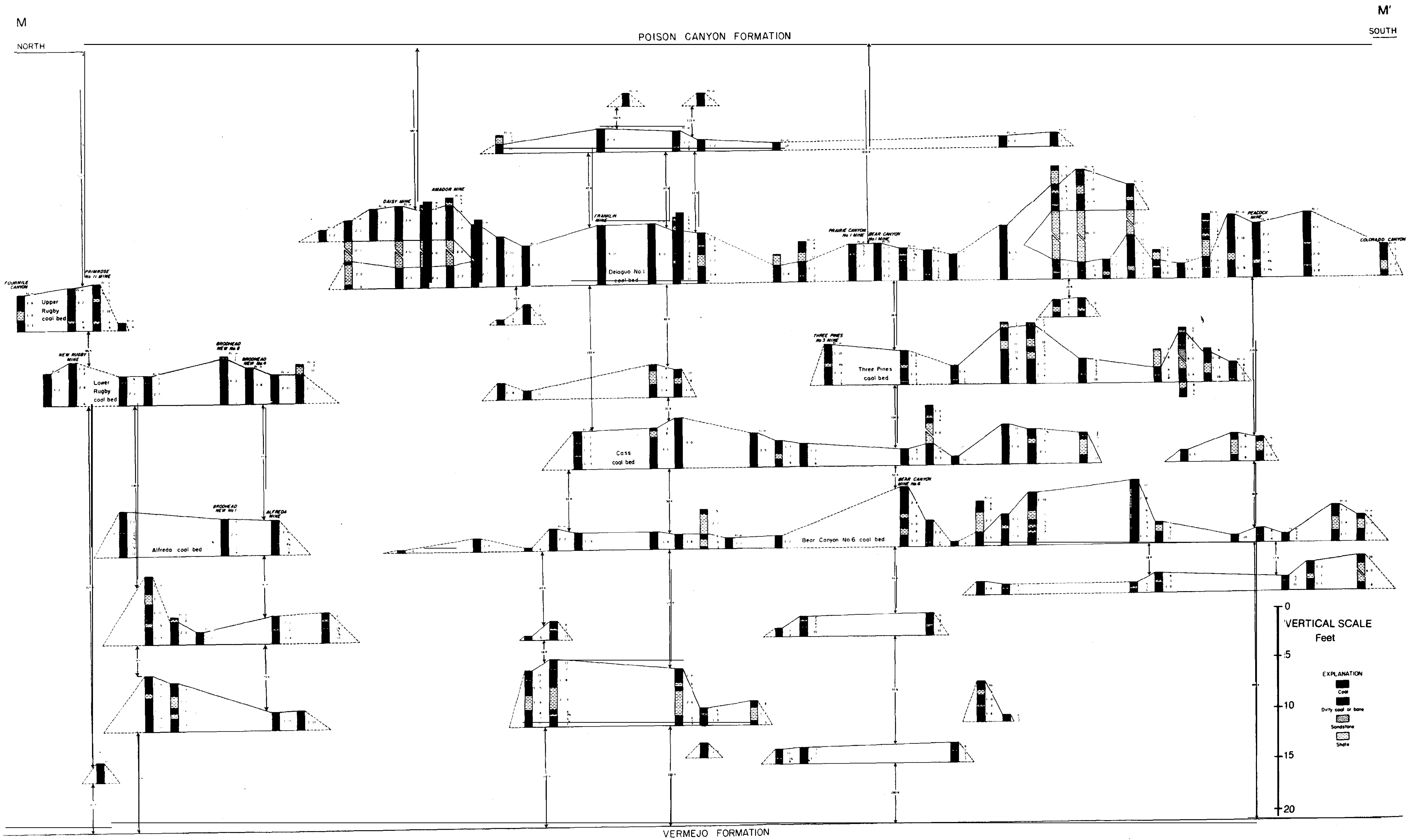


Figure 4-23. Sections of Coalbeds in the Raton Formation from Fourmile Canyon to Colorado Canyon, Las Animas County, Colorado. Reference Figure 4-15 (Harbour and Dixon, 1959)

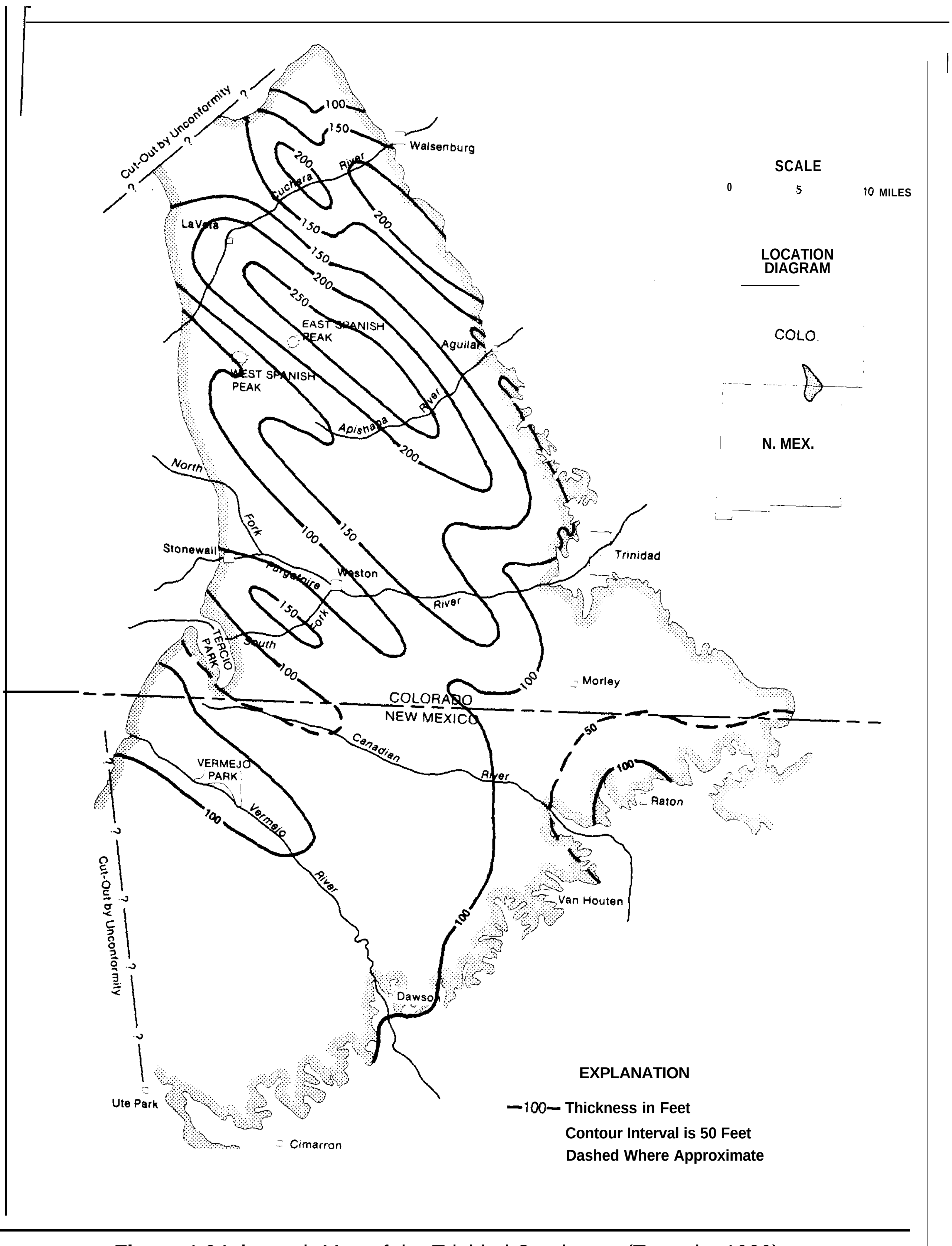


Figure 4-24. Isopach Map of the Trinidad Sandstone (Tremain, 1980)

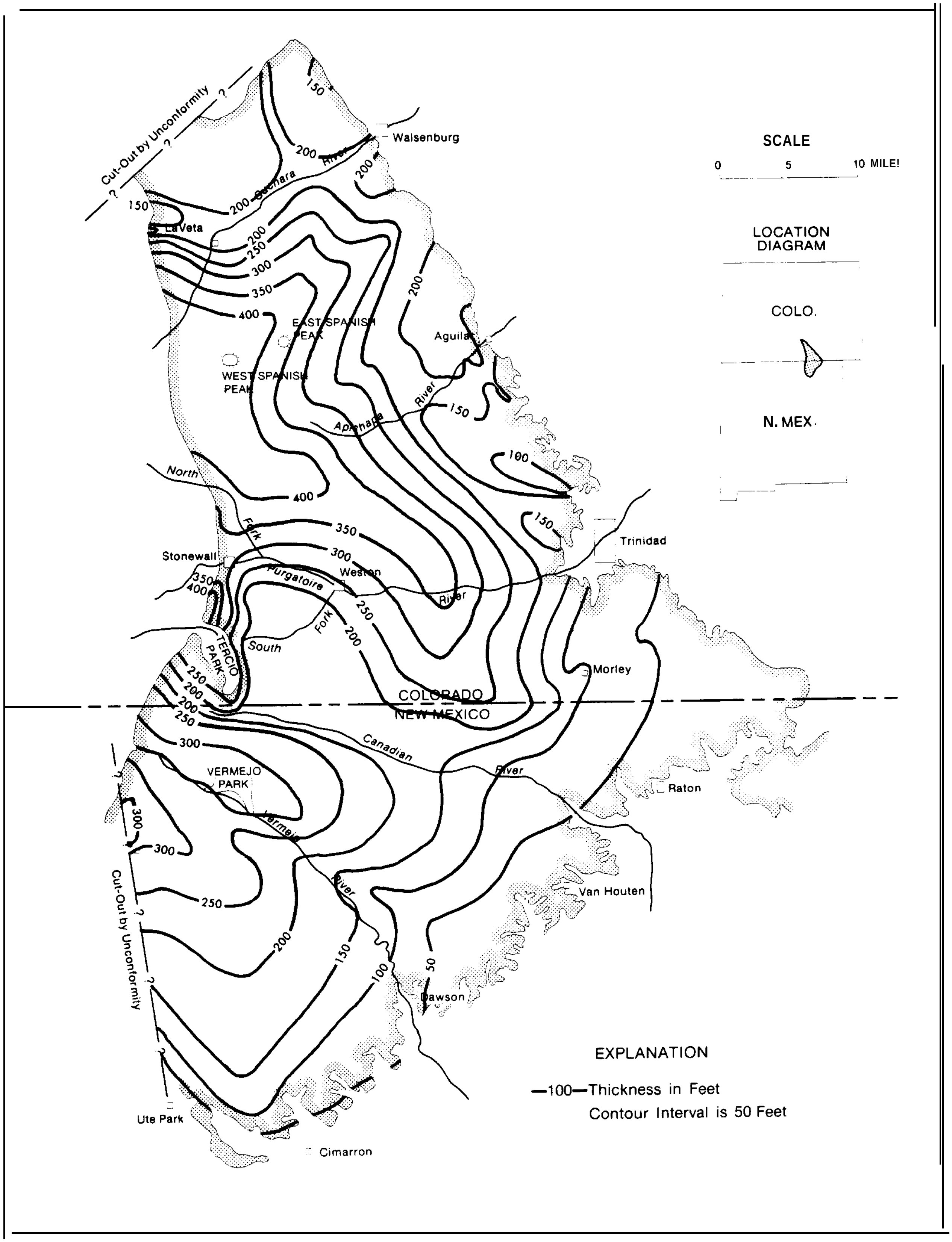


Figure 4-25. Isopach Map of the Vermejo Formation (After Tremain, 1980 and Pillmore, 1969)

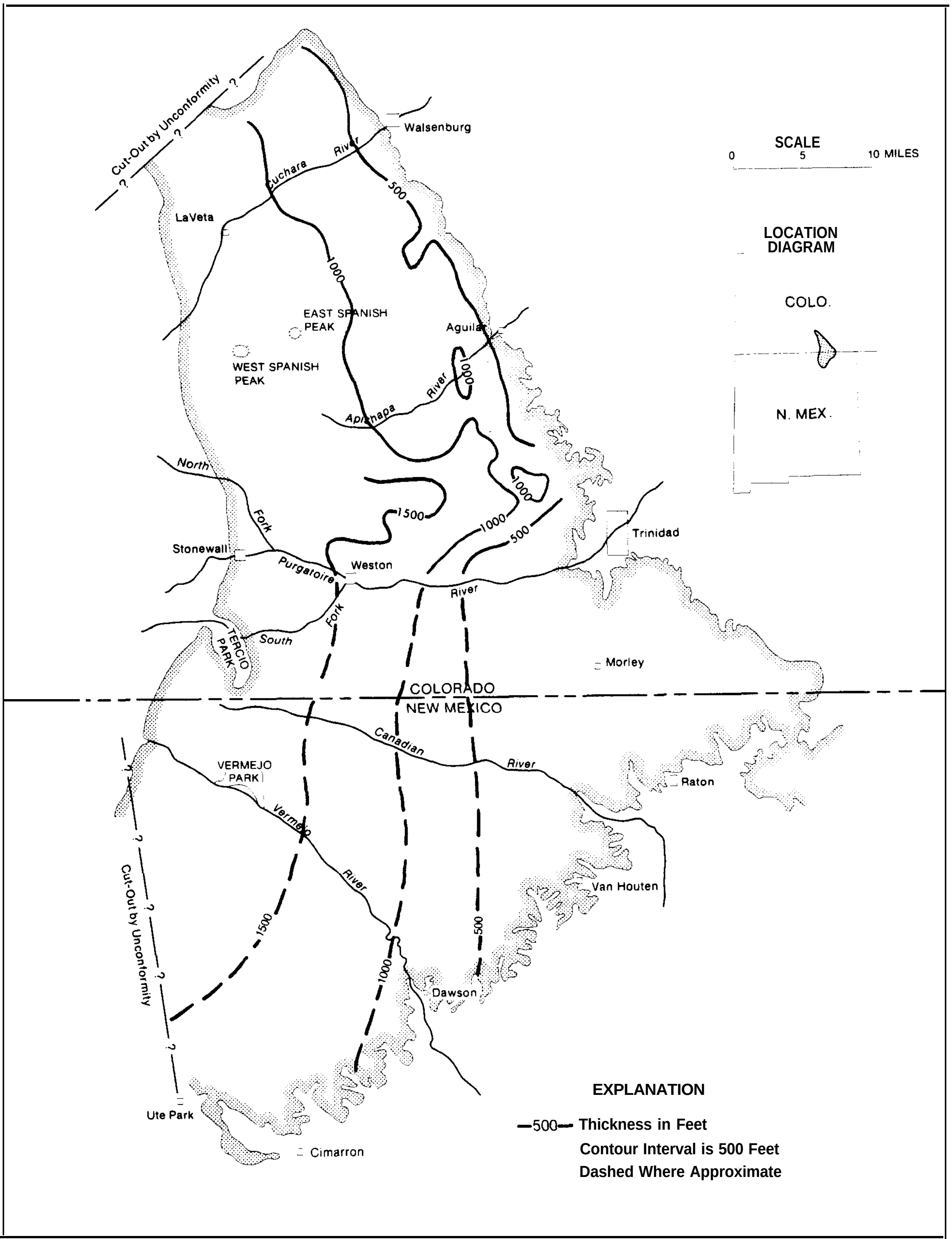


Figure 4-26. Isopach Map of the Raton Formation (After Dolly and Meissner, 1977) (Courtesy of RMAG)

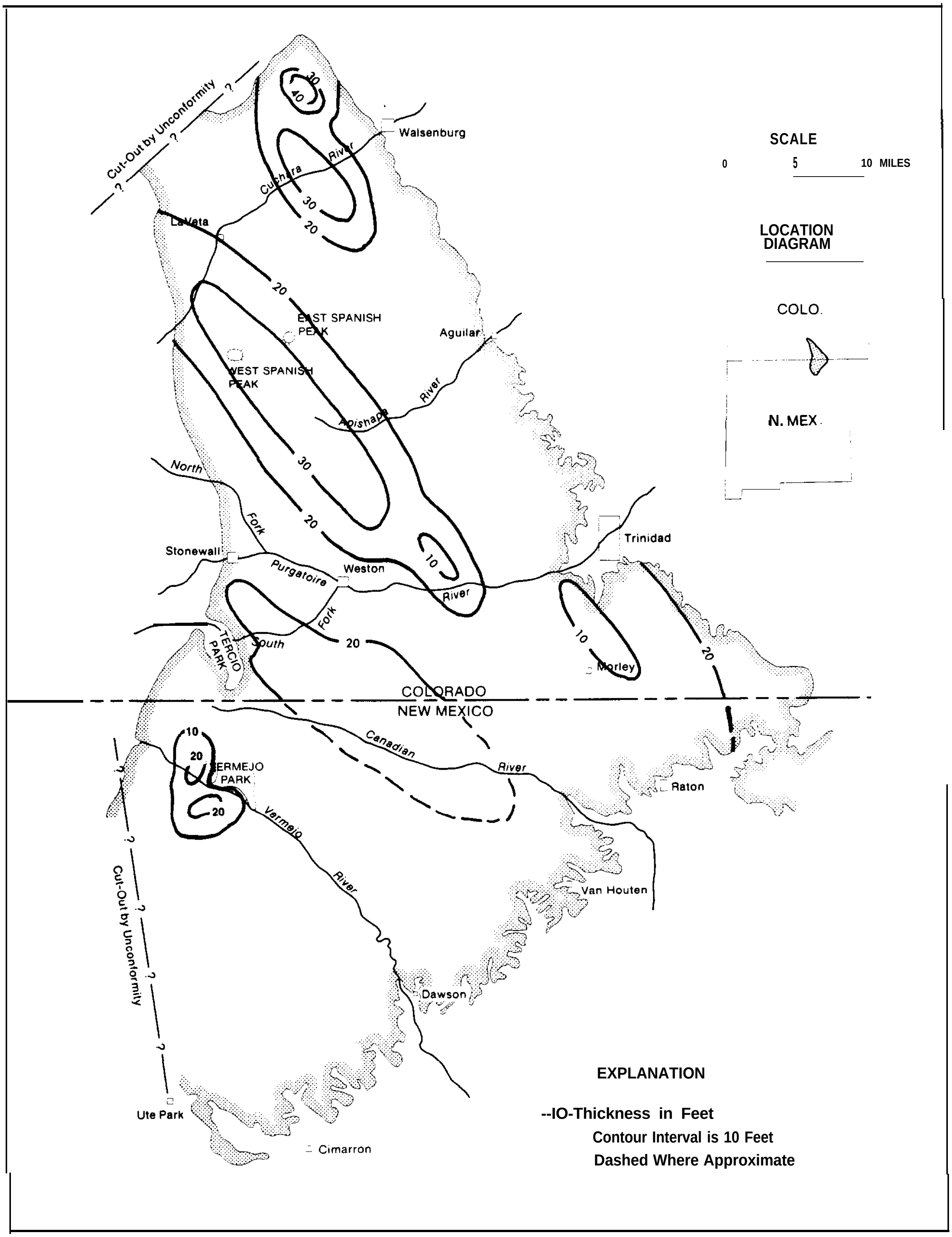


Figure 4-27. Isopach Map of the Coalbeds in the Vermejo Formation (After Tremain, 1980 and Johnson and Wood, 1956)

Figure 4-28. LANDSAT Imagery of the Raton Basin Showing the Outline of the Raton Mesa Region

Table 4-1. Range of Typical Analyses of Coalbeds in the Raton Coal Field

FORMATION	COALBED	MOISTURE'	VOLATILE MATTER	FIXED CARBON	ASH	SULFUR	BTU
VERMEJO	Raton	1 .o-9.2	30.1-9.2	43.5-50.9	6.7-22.8	0.4-0.8	10380-l 2990
	Vermejo”	—	28.2	53.7	18.0	0.5	10030
	Sugarite	2.9-3.8	38.1-39.7	48.7-49.1	8.7-8.9	0.5-0.6	13000-13300
RATON	Potatoe Canyon”'	1.5	35.1	53.6	9.8	0.5	13410
	Tin Pan”'	2.6	36.1	45.3	16.1	0.6	12150
	Yankee	5.0-6.1	35.2-37.4	42.1-48.3	9.5-16.6	0.5-l .o	12000-12700
	Chimney Divide” (Ridge)	—	38.4	47.6	13.4	0.5	13980
	York Canyon	1.7-2.2	33.3-36.1	45.3-54.0	8.0-19.2	0.4-0.6	11810-13550
	Ancho Canyon”	—	36.6	54.0	8.6	0.5	13840
	Upper Left Fork	1.5-2.1	36.1-36.7	50.8-54.4	7.5-10.4	0.4-0.6	12830-l 3740

*Unless otherwise stated, all analyses are on an “as-received” basis.
“Representative moisture-free analyses of coalbeds.
‘*‘Only one sample analysis available.

Table 4-2. Range of Typical Analyses of Coalbeds in the Trinidad and Walsenburg Coal Fields

FORMATION	COALBED/ COAL ZONE	MOISTURE*	VOLATILE MATTER	FIXED CARBON	ASH	SULFUR	BTU
VERMEJO	Cameron, Lower Bunker	1.9-7.5	31.4-39.9	45.1-57.5	8.1-14.5	0.5-l .o	11280-13510
	Berwind. Upper Bunker	1.7-5.9	31.4-33.6	51.8-54.4	10.4-15.4	0.6-0.9	11990-l 3240
	Majestic, Mammoth, Piedmont, Starkville, Walsen	1.7-10.2	28.7-41.8	44.2-58.0	4.8-19.2	0.4-l .1	10740-l 3520
	Empire, Upper & Lower Ludlow, Majestic, Pryor	2.2-6.1	29.1-37.0	48.3-54.8	8.2-18.0	0.6-l .9	11390-l 3420
	Hastings and Robinson	1.5-7.3	28.2-41.5	48.6-56.9	8.1-17.7	0.5-0.8	12050-l 3660
	Cokedale, Kebler. Occidental, Rapson, Thompson	2.3-5.2	25.8-38.6	49.4-57.3	10.2-17.7	0.5-0.6	11810-12850
	Gem and Sopris	1.9-2.1	28.2-35.5	51.9-56.9	10.7-l 7.7	0.7	12360-13110
	Apache"	3.1	34.6	54.8	10.6	0.4	13440
RATON	Alfreda, Bear Canyon, Cass, Frederick	1.8-4.4	30.3-40.7	48.1-58.3	6.1-16.4	0.4-0.8	12520-t 3550
	Delagua and Peacock	1.9-4.3	36.2-39.1	47.7-52.0	7.2-15.9	0.5-0.8	12110-13160
	Primer0	1.4-4.4	30.8-40.8	44.1-58.0	7.5-21.4	0.5-l .5	11260-l 3850
	Boncarbo	1.4-4.4	30.8-40.8	44.1-58.0	7.5-21.4	0.5-l .5	11260-l 3850

*Unless otherwise stated, all analyses are on a "as-received" basis.
*'Only one sample analysis available.

Table 4-3. Total Estimated Original Coal Reserves of **Coalbeds** At Least 14 Inches Thick With Less Than 3000 Feet of Overburden (Johnson, 1961 and Pillmore, 1969)

STATE	AREA	**COALBED** BASIS'	COAL ZONE BASIS"	TOTAL
Colorado	La **Veta**	120.9	201.9	322.8
	Walsen burg	887.5	974.4	**1.841.9**
	Spanish Peaks	106.8	388.8	493.4
	Trinidad-Aguilar	**1,215.6**	1669.7	**3,085.3**
	Gulnare, Cuchara Pass, and Stonewall	524.1	**1,755.9**	**2,280**.1
	Cuarto	262.1	768.0	**1,030**.1
	Stonewall-Tercio	491.0	**1,895**.1	2.386.1
	Starkville-Weston	880.3	4.364.7	5.2445
			Subtotal	**16,484**.2
New Mexico	Castle Rock	400.0	—	400.0
	Gardner	184.0	—	184.0
	Yermejo Park	24.7	—	24.7
	York Canyon	241.9	—	241.9
			Subtotal	850.6
			Grand Total	**17,334**.8

'All figures are in thousands of short tons
'*Additional estimates of reserves on a zone basis are based on the assumption that the coal-bearing rocks contain as much coal as depth as at the outcrop.

Table 4-4. Estimated Original Reserves by Coalbed for the Vermejo Formation

COAL FIELD	COAL BED/ZONE	MEASURED?	INDICATED	INFERRED	TOTAL
Raton	Raton		—	—	200
	Vermejo		—	—	200
Trinidad & Walsenburg	Berwind		28.9	38.6	85.5
	U. Bunker Hill		11.3	34.8	48.1
	Bunker Hill		2.7	17.6	20.3
	L. Bunker Hill		4.9	23.4	28.3
	Cameron		27.3	28.8	56.1
	Cokedale		31.0	18.1	47.1
	Empire		13.7	7.2	20.9
	Gem		8.2	3.5	9.7
	Hastings		20.6	56.8	77.4
	Lenox		51.4	85.7	137.1
	U. Ludlow		5.8	1.5	7.3
	L. Ludlow		15.7	14.2	29.9
	Majestic		31.0	46.1	77.1
	Morley		24.8	28.7	53.3
	New Rouse		25.6	47.9	73.5
	Piedmont		16.1	58.5	74.6
	L. Piedmont		4.0	20.2	24.2
	Pryor		40.0	60.2	100.2
	Rainbow		29.8	72.5	102.3
	Rapson		16.6	70.9	87.5
	U. Robinson		39.5	31.6	71.1
	L. Robinson		43.8	16.9	80.7
	Sporis		29.3	42.2	71.5
	L. Sopris		1.5	1.7	3.2
	U. Starkville		1.5	2.3	3.8
	L. Starkville		11.6	8.7	19.9
	Thomas		1.7	0.9	2.6
	Walsen		36.9	27.6	84.5
	Others		102.6	54.5	157.1
			GRAND TOTAL		1992.8

†All figures are in thousands of short tons. Where no value for measured reserves is given, the value under the indicated column represents estimated measured and indicated reserves

Table 4-5. Estimated Original Reserves by Coalbed for the Raton Formation

COAL FIELD	COAL BED/ZONE	MEASURED†	INDICATED	INFERRED	TOTAL
Raton	Ancho Canyon	21.5	6.4	10.5	38.4
	Chimney Divide	48.3	29.3	19.9	97.5
	Cottonwood Canyon	19.0	23.0	9.0	51.0
	Left Fork	13.3	5.5	5.9	24.7
	York Canyon	55.0	—	—	55.0
Trinidad & Walsenburg	Alfreda		5.8	5.1	10.9
	Bear Canyon No. 6		18.0	8.6	24.6
	Boncarbo		30.6	40.9	71.5
	Cass		18.8	15.3	34.1
	Ciruela		15.9	30.0	45.9
	Delagua No. 1		81.4	53.7	115.1
	Frederick		85.7	27.8	113.5
	Martinez		4.3	7.5	11.8
	Mutual		21.4	31.7	53.1
	Primer0		52.8	57.7	110.5
	U. Rugby		4.9	13.3	18.2
	L. Rugby		12.7	36.7	49.4
	Three Pines		12.8	16.3	29.1
	A		28.6	38.3	64.9
	B		4.9	13.3	18.2
	Others		123.3	144.3	267.6
			GRAND TOTAL		1305.0

†All figures are in thousands of short tons. Where no value for measured reserves is given. the value under *the* indicated column represents estimated measured and indicated reserves.

5. POTENTIAL METHANE RESOURCE

5.1 PREVIOUS METHANE CONTENT STUDIES/ANALYSES

Studies investigating the desorption of methane gas from coal in the Raton Mesa region are limited to four test holes drilled by the Colorado Geological Survey and the United States Geological Survey (USGS) along the Purgatoire River and two production holes drilled by the U.S. Bureau of Mines (USBM) near the town of Morley, Colorado. Figure 5-1 shows the location of the well test sites. Gas content of the coalbeds tested at the USGS sites ranged from 23 to 193 cubic feet per ton (cu ft/ton) for the Raton Formation coalbeds, and 115 to 492 cu ft/ton for coalbeds of the Vermejo Formation (Table 5-l). Figure 5-2 is a graphical presentation of selected data. These tests indicate the Vermejo Formation, at depths greater than 700 feet, as having the greatest potential for coalbed methane development. Bench (1979), with the United States Bureau of Mines (USBM), completed a drilling program near the Morley Dome that was aimed at producing methane from coalbeds. Although this report never was published, results of the drilling and testing indicated low methane contents south of Trinidad, Colorado. Table 5-2 summarizes the results of coalbed methane desorption work completed in the Raton Mesa region.

A second indication of methane gas associated with coalbeds comes from mine methane emission surveys. Methane emission reports are available from the United States Department of Labor Mine Safety and Health Administration (MSHA) indicating that more than 2 MMcfd are vented daily from three mines in the region. These reports cannot be used directly to estimate the gas content of a coalbed because, once mining has passed through an area, a significant portion of the methane emitted into the mine may come from adjacent strata. Figure 5-3 is an index map of the region showing locations of the operating underground coal mines. The emission data from these mines are presented in Table 5-3. The status of coal mines in the Raton Mesa region is summarized in Table 5-4.

The city of Trinidad is presently investigating the possibility of producing methane gas from the Raton coalbed of the Vermejo Formation for use as a municipal natural gas supply, Drilling and testing are being conducted on a site near the town of Weston, Colorado. Desorption of coal core samples being conducted by Colorado Geological Survey personnel indicates, as of August, 1980, contents ranging from 260 to 381 cu ft/ton.

Fender and Murray (1978) recorded 32 mines in the Colorado portion of the region with reported occurrences of gas. Figure 5-4 shows the location of coal mines associated with methane. Locations of gas shows in exploratory and water wells are shown in Figure 5-5. Other indications of the occurrence of coalbed methane in the region include two exploration wells that reported 100 percent methane background gas throughout the coal interval (Energetics Healy No. 13-8, Sec 8, T.31S., R.65W.), and the recovery of some burnable gas after fracturing a 5-foot coalbed in the Raton Formation (Filon Exploration Corporation No.1 - Zeles Hope Sec. 31, T.31S., R.65W.).

Modern geochemical theory indicates that natural gas is generated by the thermal alteration of organic material buried in sediments (Welte, 1965). The onset of measurable hydrocarbon generation occurs rather suddenly at some critical activation temperature which may be related to burial depth through the earth's geothermal gradient. Coal petrologists have demonstrated the large-scale release of methane during the transition from high-volatile C bituminous coal to those of increasingly higher rank (Francis, 1961), and the amount of volatile matter serves as a parameter for measuring the amount of devolatilization a coal has undergone. Figures 5-6 and 5-7 illustrate the progressive devolatilization of coal and the accompanying generation of methane.

The Raton Mesa region is an area of anomalously high terrestrial heat flow (Figure 3-18). This high heat flow probably is related to the Spanish Peaks intrusive and associated underlying magmatic activity. The occurrence of an area of high heat flow, igneous intrusives, and extensive low volatile-matter coalbeds in the Raton Mesa region indicates the potential generation of substantial amounts of dry methane gas.

5.2 ESTIMATED RESOURCE VOLUME

Dolly and Meissner (1977) calculated that approximately 23 trillion cubic feet of gas has been generated by the coalbeds of the Vermejo and

Raton Formations in the Trinidad and Walsenburg Coal Fields of Colorado. Their calculations were based on the following:

1) Average aggregate coal thickness - 15 feet

2) Area1 extent of coal - 1,200 square miles

3) Coal density - 1,800 tons per acre foot

4) Weight of coal

$$\text{Thickness} \times \text{Area1 extent} \times \text{Density} = 15 \times 1200 \times 640 \times 1800$$
$$= 20.74 \times 10^9 \text{ tons}$$

5) Average coal rank is approximately a medium-volatile bituminous coal containing 26 percent volatile matter, and has generated 1,121 cubic feet of gas per ton.

6) Volume of gas generated

$$\text{Weight of coal} \times \text{volume of gas per ton} = 20.74 \times 109 \times 1121$$
$$= 23.2 \times 10^{12} \text{ cubic feet.}$$

If Dolly and Meissner's (1977) calculations are expanded to include the Raton Coal Field with its 800 square miles, an estimated 38.7 trillion cubic feet of gas has been generated by the Vermejo and Raton Formations.

Assuming that approximately 50 percent of the original gas generated is still confined within the coalbeds, approximately 18.4 trillion cubic feet of gas is still in place in the Raton Mesa region.

Danilchik and others (1979) estimated that approximately 84 billion cubic feet of methane gas is present in coalbeds of the Vermejo Formation underlying an area of 25 square miles located along the Purgatoire River. His estimate is based on the results of the coal desorption work completed by the U.S.G.S., and the assumption that a 7-foot thickness of coal is present throughout the entire area at depths ranging from 1,500 to 2,000 feet deep, and containing at least 416 cubic feet of gas per ton of coal.

An estimate of the coalbed methane resource for 54 square miles in the Trinidad Coal Field totals 311 billion cubic feet for a lo-foot thick coalbed (Tremain, 1980). Tremain presently is compiling a set of over-burden and coal isopach maps for the Trinidad and Walsenburg Coal Fields in an effort to estimate more accurately the coalbed methane resource.

If Danilchik's estimate is expanded to include the entire Raton Mesa region, approximately 8 trillion cubic feet of methane gas is present in-place in the coalbeds. If Tremain's resource estimate is expanded accordingly, there is approximately 12 trillion cubic feet of in-place coalbed methane gas in the Raton Mesa region.

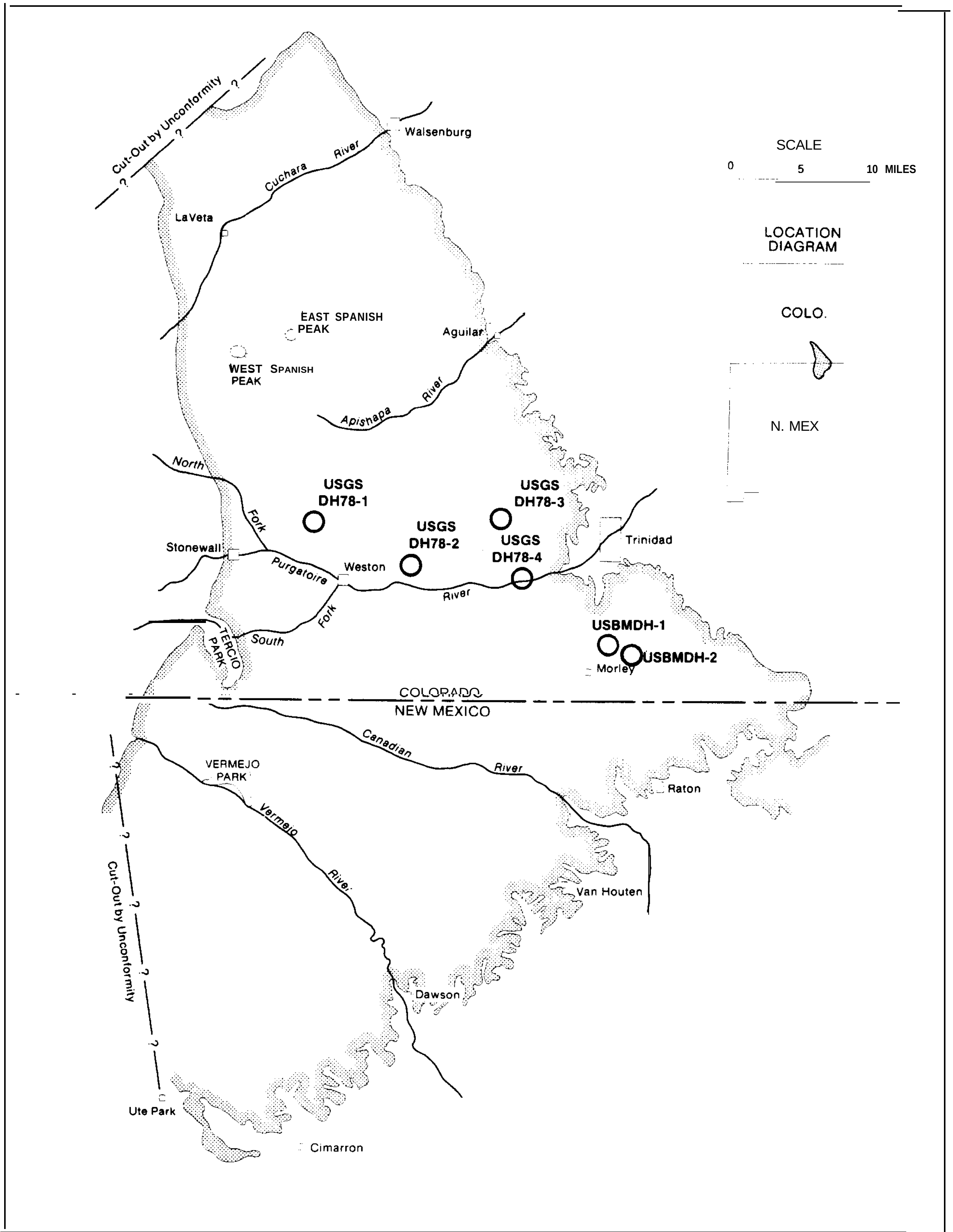


Figure 5-1. Exploratory Drill Sites in the Raton Mesa Region

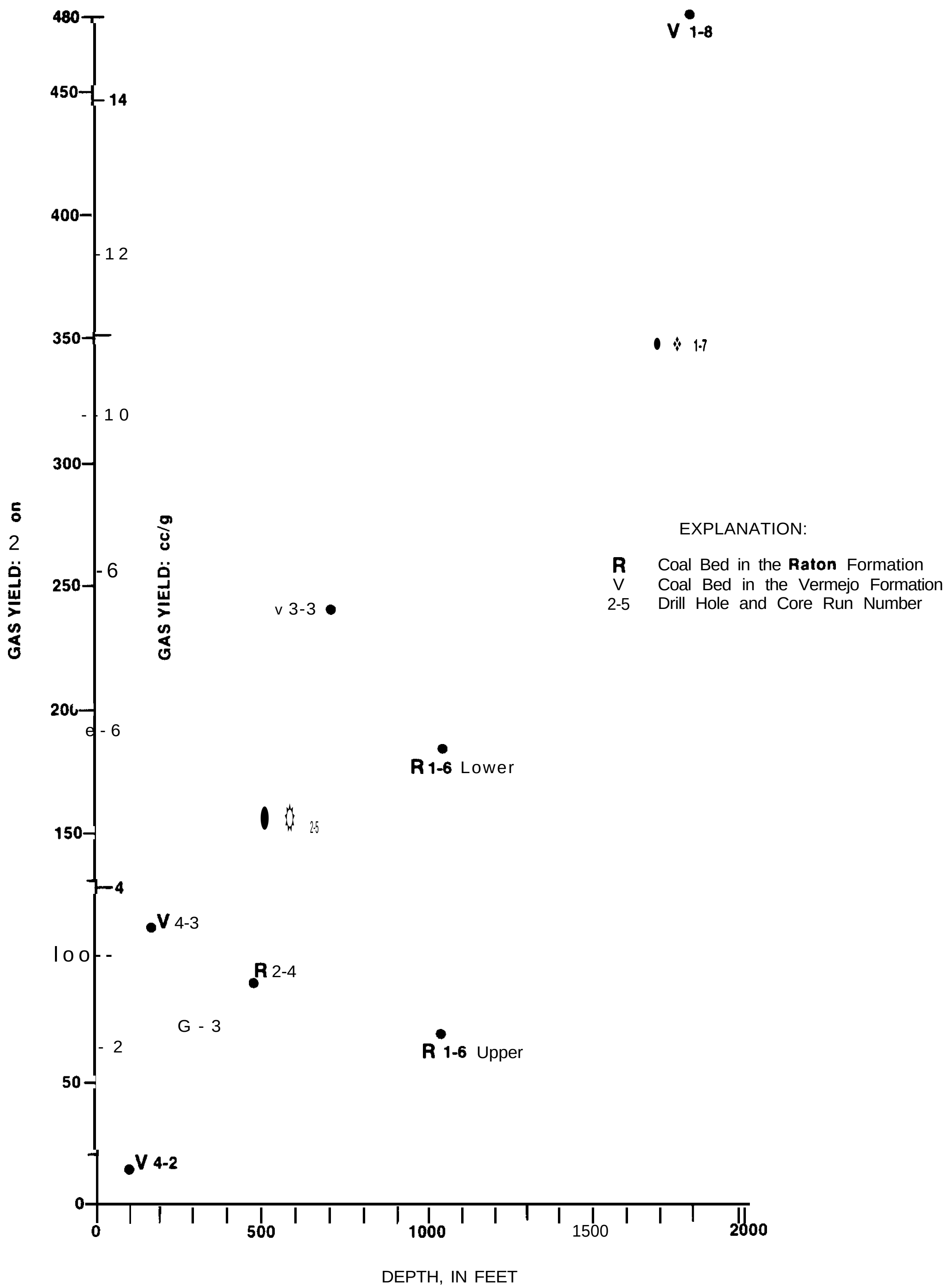


Figure 5-2. Depth vs. Gas-Yield Relationships of Selected Coal Core Samples from the Raton and Vermejo Formations, Las Animas County, Colorado (After Danilchik, et al, 1979)

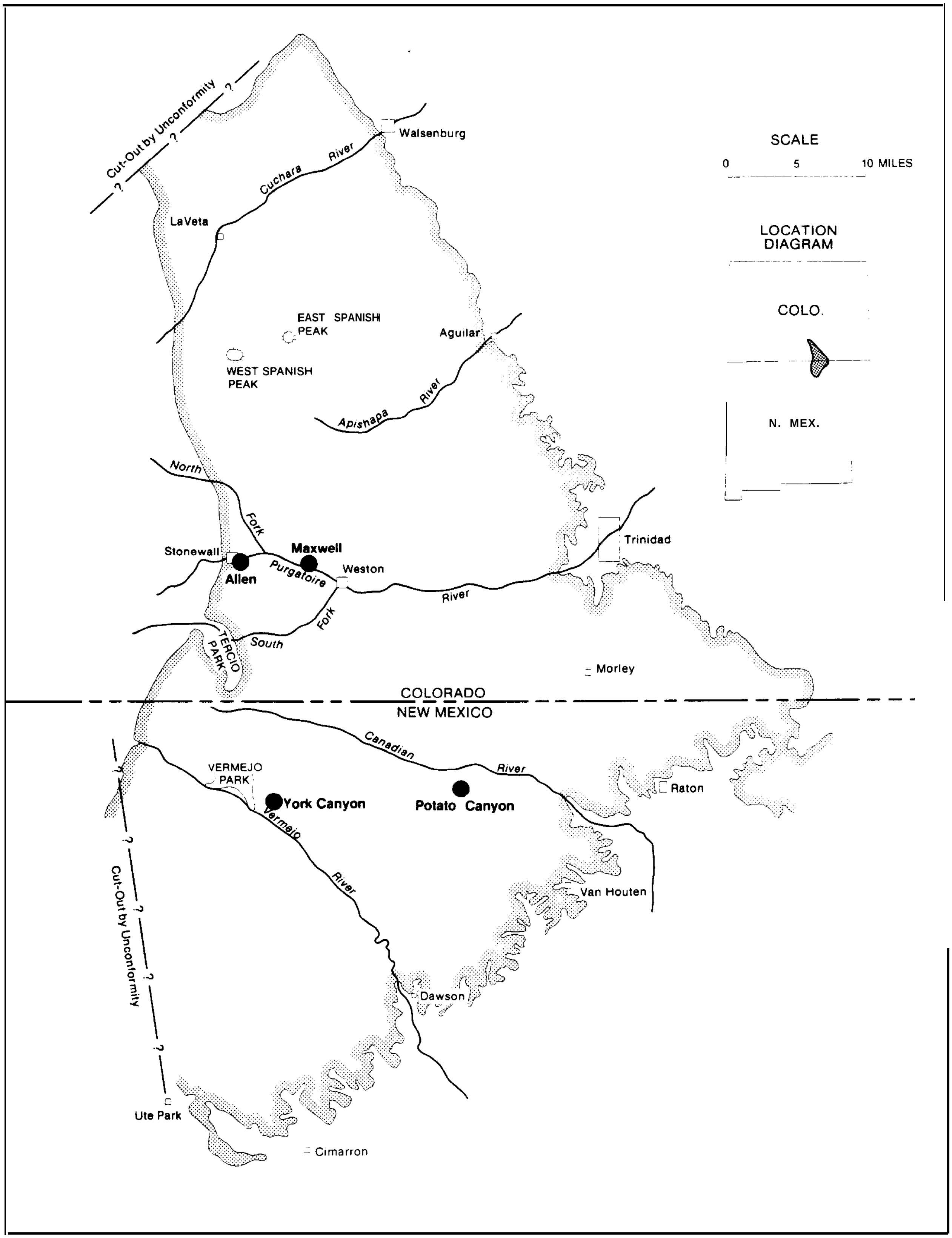


Figure 5-3. Active Underground Coal Mines in the Raton Mesa Region

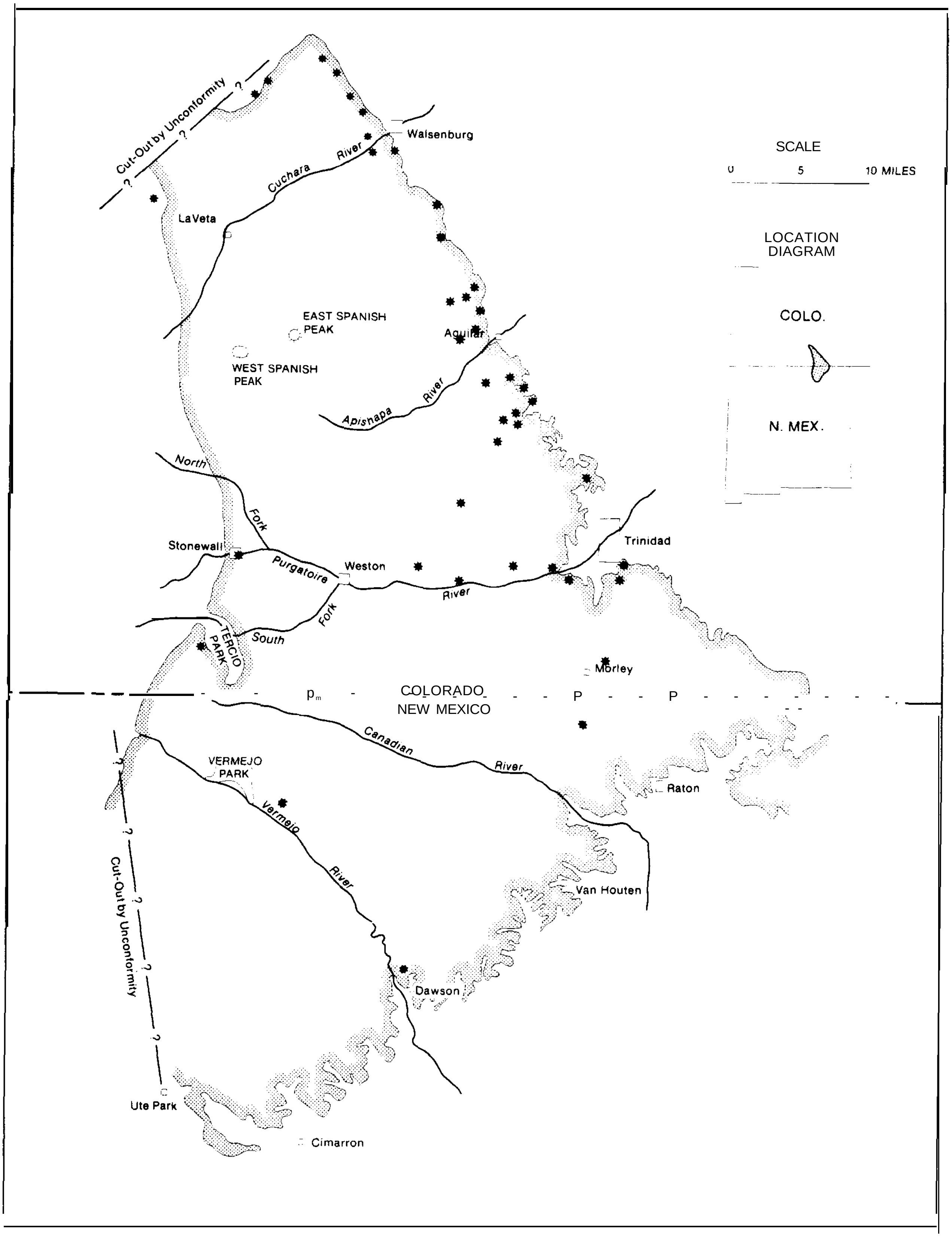


Figure 5-4. Gassy Mines in the Raton Mesa Region (After Fender and Murray, 1978)

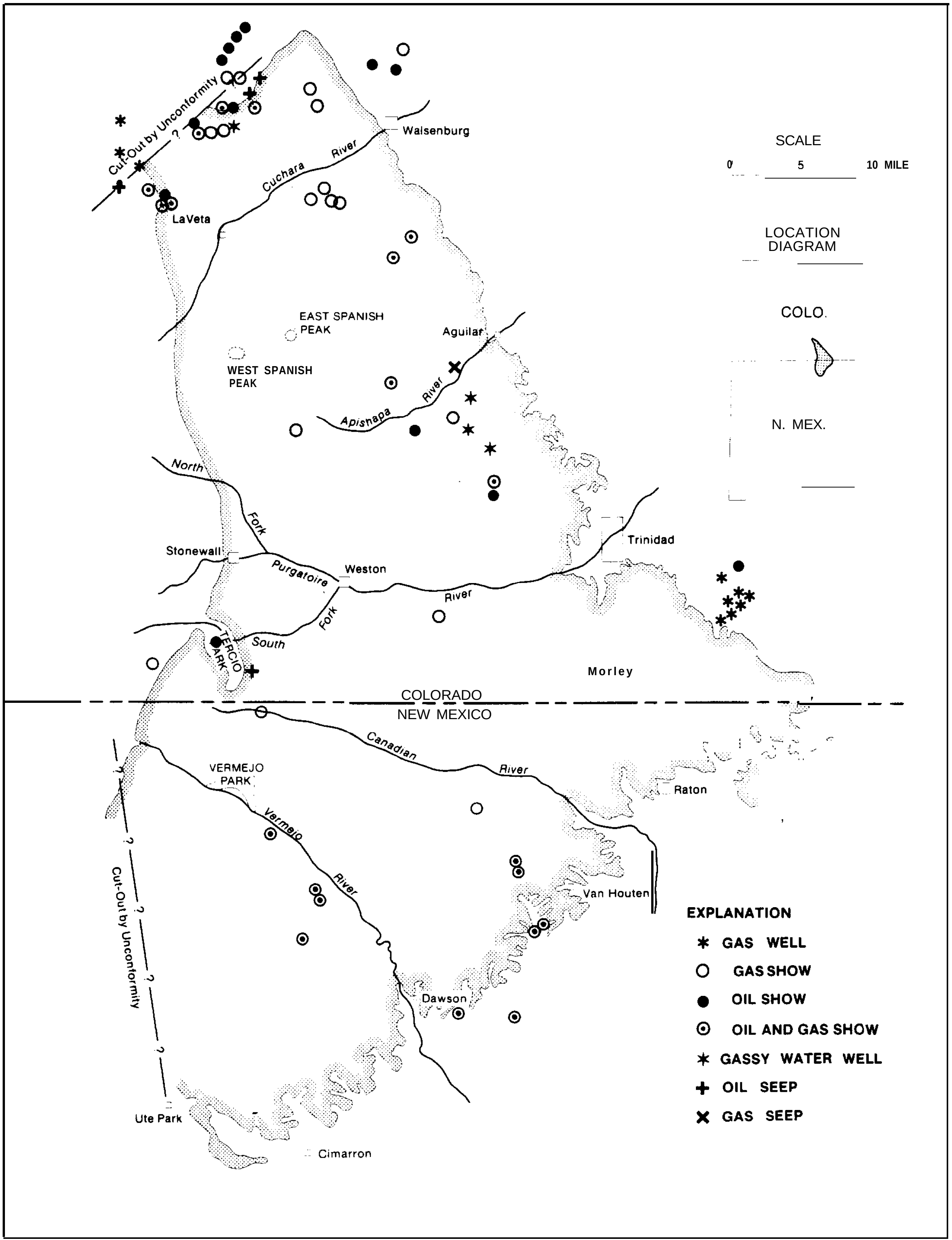


Figure 5-5. Oil and Gas Shows in the Raton Mesa Region (After Tremain, 1980 and Speer, 1976)

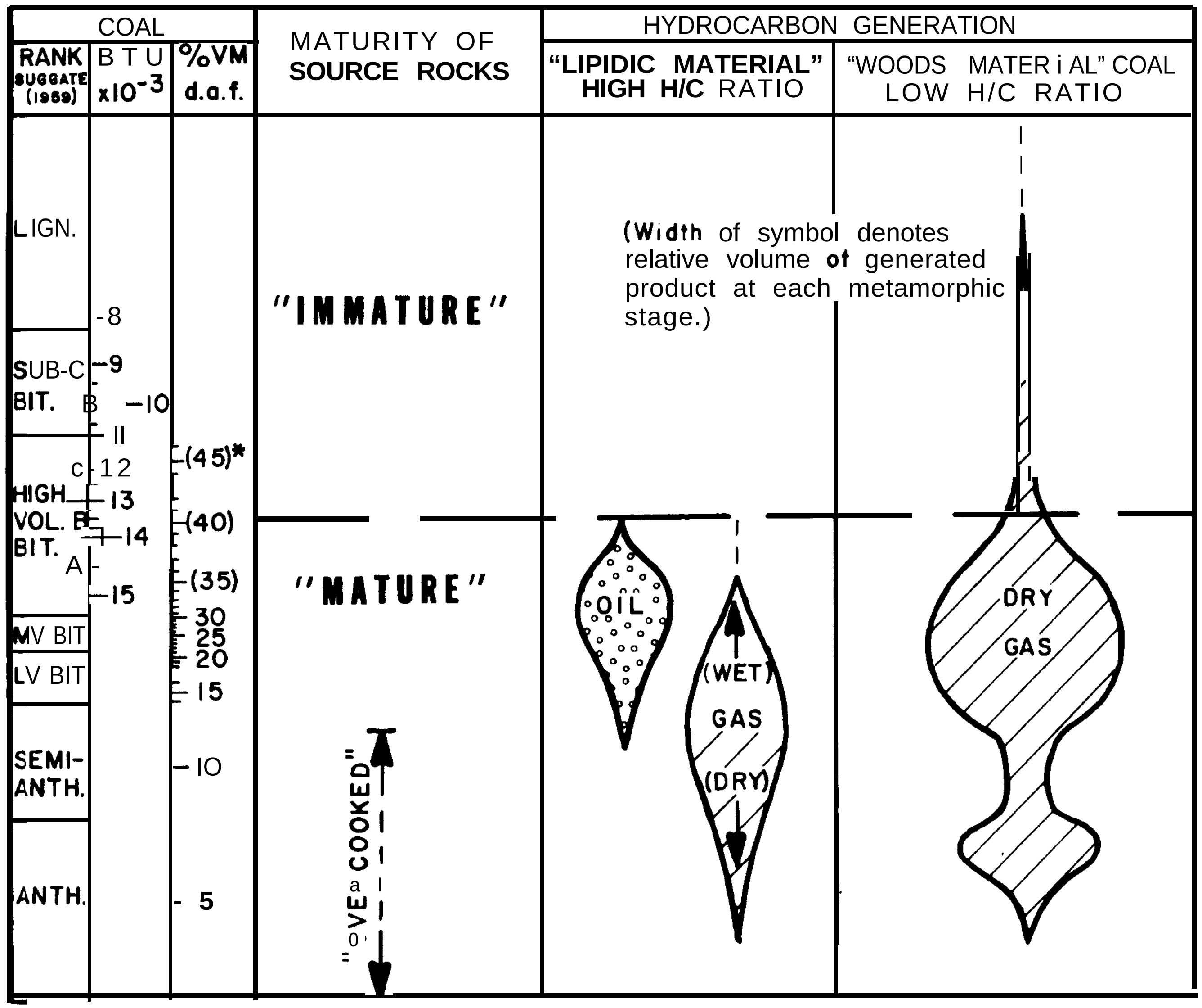
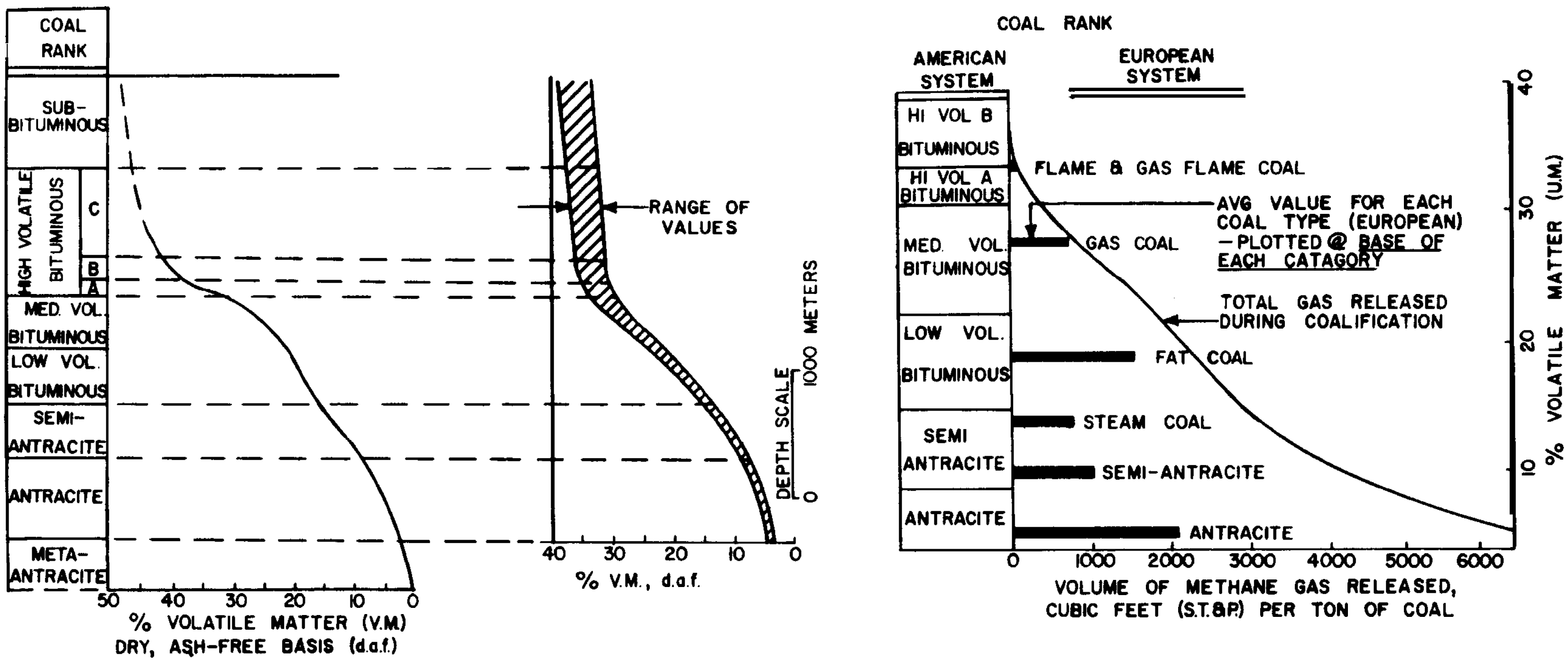


Figure 5-6. Organic Metamorphism of Coals and its Relation to Hydrocarbon Generation in Two Main Types of Organic Material Deposited in Sediments (Dolly and Meissner, 1977) (Courtesy of RMAG)



A> COAL VS. VOLATILE MATTER CONTENT, ASTM STD (1954), EXTENDED TO RANKS LOWER THAN HI-VOL-C BITUMINOUS BY HOOD ET AL, (1975) FOR HUMIC COALS.

B) COAL RANK AND DEPTH VS. VOLATILE MATTER IN COALS FROM THE RUHR DISTRICT, GERMANY (AFTER PATTIESKY & TEICHMULLER, 1960; TEICHMULLER, 1966)

C) GENERATION OF METHANE GAS DURING THE ORGANIC METAMORPHISM OF DIFFERENT RANKS OF BITUMINOUS & ANTRACITE COALS (BASED ON JUNTCEN & KARWEIL, 1966)

Figure 5-7. Organic Metamorphism of Coals and its Relation to Devolatilization and Methane Generation (Dolly and Meissner, 1977) (Courtesy of RMAG)

Table 5-1. Quantity of Gas Desorbed from Coal, Coke and Shale from Four U.S. Geological Survey Core Holes, Raton Mesa Region, Las Animas County, Colorado (Danilchik, et al, 1979)

CORE HOLE NUMBER A LOCATION	CORE RUN NUMBER	DESCRIPTION	FORMATION	SAMPLE DEPTH (FT)	THICKNESS		SAMPLE WEIGHT (g)	LOST GAS (cc)	DESORBED GAS (cc)	/RESIDUAL GAS (cc/g)	TOTAL GAS'	
					BED	CORE					(cc/g)	(cf/ton)
USGS DH 76-I SE¼, SE½ Sec 4. T 33 S., R 67 W	5 Upper bed	Coke	Raton	810-811	13	13	2m319	370	3 086	0 10	1 6	51
	5 Lower bed	Coaly shale	Raton	828 2-828 6	0 5	0 5	1.096	130	755	0 0	81	26
	6 Upper bed	Coal, banded	Raton	1.0535-1.0539	0 4	0 4	2,306	480	4.731	0 0	2 3	74
	6 Lower bed	Coal, broken	Raton	1.063 I-I.064 1	21	13	1.710	850	9 446	0 01	6 0	193
	7	Coal. bright broken	Vermejo	1,691 Z-I.6922	5 6	4 2	1.600	3,400	14.255	0 04	11 0	350
	8	Coal, dull pyritic	Vermejo	1.792-1.793	3 0	1 6	1,724	6.300	16.096	0 06	150	492
USGS DH 78-2 NE¼, SW¼, SE¼ Sec 27, T 33 S R 66 W	3	Coal. bright	Raton	306 3-310 5	2 2	2 2	1,461	170	3.390	0 16	2 6	83
	4	Coal, blocky	Raton	462 65-483 6	1 4	1 0	1,057	890	2,031	0 0	2 6	88
	5	Coal, blocky	Raton	499 7.501	2 4	2 0	767	1.110	2.719	0 0	5 0	160
USGS DH78-3 NW½, NW'!. SW½ Sec 2. T 33 S., R 65W	3	Coal. bright	Vermejo	729 4-732 5	3 2	31	1.768	3.300	10.176	0.33	7 9	254
USGS DH78-4 C Sec 36. T 33S.R 65W	2	Coal. blocky	Vermejo	100 5-101 05	21	21	808	170	158	0 3	71	23
	3	Coal dull	Vermejo	167 9-168.45	19	0 55	553	800	1.057	0 2	3 6	115

'Total Gas Content $= \frac{\text{Lost Gas (cc)} + \text{Desorbed Gas (cc)}}{\text{Sample Weight (g)}} + \text{Residual Gas (cc/g)}$

Total Gas (cc/g) x 32 = Total Gas (cf/ton)

Table 5-2. Desorption Results for the Raton Mesa Region (Tremain, 1980)

FIELD	DRILL HOLE	TEST NO.	FORMATION	DEPTH TO BED (m)	DEPTH TO BED (ft)	SAMPLE WEIGHT (g)	DESORBED GAS (cm³)	LOST GAS (cm³)	RESIDUAL GAS (cm³/h)	TOTAL GAS (cm³/g)	TOTAL GAS (ft³/ton)	APPARENT RANK OF COAL	% METHANE IN GAS (AIR FREE)	HEATING (kcal/m³)	VALUE OF GAS (Btu/ft³)
TRINIDAD		1	Raton	246.89	810.0	2319	3086	370	0.10	1.59	51	an[1]	66.78	6282	698
		2	Raton	252.37	828.0	1098	755	130	0.0	0.81	26	hvCb[2]	—	—	—
	USGSDH78-1	3	Raton	321.11	1053.5	2308	4731	480	0.0	2.26	74	hvBb[3]	91.75	8233	925
		4	Raton	324.03	1063.1	1710	9441	850	0.01	6.03	193	mvb[4]	83.34	7485	841
		5	Vermejo	515.48	1691.2	1600	14255	3400	0.04	11.07	350	mvb	46.14	4139	465
		6	Vermejo	546.20	1792.0	1724	18098	8300	0.06	15.37	492	mvb	97.16	8722	980
		7	Raton	94.24	309.2	1461	3390	170	0.16	2.60	83	lvb[5]	—	—	—
	USGSDH78-2	8	Raton	146.97	482.2	1057	2031	890	0.0	2.76	88.4	mvb	—	—	—
		9	Raton	152.31	499.7	767	2719	1110	0.0	4.99	160	mvb	—	—	—
	USGSDH78-3	10	Vermejo	222.32	729.4	1768	10176	3300	0.33	7.95	254	mvb	98.98	8873	997
	USBMDH-1	11	Vermejo	30.63	100.5	808	158	170	0.30	0.71	23	mvb	—	—	—
		12	Vermejo	51.18	167.9	553	1057	800	0.20	3.56	115	mvb	—	—	—
		13	Vermejo	218.11	715.6	876	88	—	1.35	1.45	46	hvAb[6]	—	—	—
		14	Vermejo	246.89	810.0	1051	74	115	0.0	0.18	6	hvAb	—	—	—
	USGSDH78-4	15	Vermejo	247.65	812.5	1657	56	65	0.0	0.07	2	hvAb	—	—	—
		16	Vermejo	261.37	857.5	1107	4409	280	0.60	4.84	155	hvAb	81.62	7316	822
		17	Vermejo	265.02	869.5	1661	6589	360	0.40	4.58	147	hvAb	81.49	7307	821
		18	Vermejo	266.70	875.0	1223	3183	100	0.50	3.20	102	hvAb	—	—	—
		19	Vermejo	264.57	868.0	1035	505	70	0.60	1.16	37	hvAb	—	—	—
		20	Vermejo	265.94	872.5	1122	220	10	0.14	0.40	13	hvAb	—	—	—
		21	Vermejo	293.13	961.7	753	260	130	0.61	1.13	36	hvAb	—	—	—
	USBMDH-2	22	Vermejo	293.80	963.9	1014	270	70	0.69	1.03	33	hvAb	—	—	—
		23	Vermejo	306.48	1005.5	1152	745	130	0.44	1.20	38	hvAb	—	—	—
		24	Vermejo	308.70	1012.8	796	445	170	1.90	2.70	86	hvAb	—	—	—
		25	Vermejo	313.67	1029.1	809	320	90	1.20	1.71	55	hvAb	—	—	—
		26	Vermejo	313.94	1030.0	938	335	160	1.11	1.64	52	hvAb	—	—	—
		27	Vermejo	313.94	1030.0	478	847	200	0.65	2.84	91	hvAb	—	—	—
WALSENBURG		28	Vermejo	33.83	111.0	1049	51	75	0.36	0.93	30	hvCb	—	—	—
		29	Vermejo	47.24	155.0	1211	82	241	0.41	1.08	35	hvCb	—	—	—
		30	Raton	205.65	674.7	315	185	300	0.10	1.60	53	hvAb	—	—	—
		31	Raton	273.10	896.0	352	157	370	0.0	1.50	48	hvAb	—	—	—
		32	Vermejo	346.47	1136.7	549	134	550	0.80	2.05	66	hvAb	—	—	—
		33	Vermejo	306.81	1006.6	369	32	300	0.0	0.90	29	hvAb	—	—	—
		34	Vermejo	308.64	1012.6	584	54	30	0.0	0.14	5	hvAb	—	—	—
		35	Vermejo	327.20	1073.5	257	48	90	0.0	0.54	17	hvAb	—	—	—

1 anthracite
2 high-volatile C bituminous coal
3 high-volatile B bituminous coal
4 medium-volatile bituminous coal
5 low-volatile bituminous coal
6 high-volatile A bituminous coal

Table 5-3. Coal Mine Methane Emission Survey from MSHA 2nd Quarter, 1980 Mine Inspection Report

MINE/BED	LOCATION	AVE. DAILY PRODUCTION (TONS)	AVE. METHANE EMISSION (cf/24 hr.)	AVE. METHANE CONTENT (d/ton)
Allen/Allen (Ciruela)	Sec 23 T 32SR68W	2,695	527,000	195
Maxwell/Apache	Sec 29, T33S, R67W	903	654,000	724
York Canyon/York Canyon	Sec 34, T31N, R19E	3,961	677,000	221

Table 5-4. Summary of Coal Mining Activity in the Raton Mesa Region

MINE/COUNTY	TYPE[1]	STATUS[2]
Allen/Las Animas	U	Active
Maxwell/Las Animas	U	Active
Helen/Las Animas	U	Temporarily Closed
Jewell/Las Animas	S	Temporarily Abandoned
Healey/Las Animas	S	Active
Delagua/Las Animas	S	Temporarily Abandoned
Baldy/Las Animas	S	Active - Not Producing - Man
Viking/Las Animas	S	Active
Las Animas/Las Animas	S	Active
Cullen/Huerfano	S	New - No Men Working
York Canyon/Colfax	U	Active
Potatoe Canyon/Colfax	U	New
West York/Colfax	S	Active

[1] U - Underground
S - Surface

[2] MSHA Coal Mine Inspection Status List - 5/3/80

6. CONCLUSIONS AND RECOMMENDATIONS

The Raton Mesa region contains substantial resources of high- and medium-volatile bituminous coals which extend from outcrops along the periphery of the region to depths of at least 3,000 feet in the deepest parts of the region. Potentially, methane gas associated with the deeper of these coalbeds is very substantial. Although methane characterization data are limited to six test sites near the Purgatoire River and at the Morley Dome in the Trinidad Coal Field, and two test sites in the Walsenburg Field, test results indicate substantial methane content in higher rank coalbeds of the Vermejo Formation in the western part of the region. Development of a data base framework is required to fully characterize overall distribution of the coalbed methane resource in the Raton Mesa Region.

The initial phase in development of that data base will be delineation of a primary target area. The primary target area as shown in Figure 6-1 encompasses the majority of the Raton Mesa region. The target area does not include the periphery of the region. Here, where the coal is not mined out, it is either very shallow or outcropping, thus allowing methane gas to escape into the atmosphere. The target area also does not include areas where there has been extensive igneous intrusive activity. In those areas, significant amounts of coal have been intruded and destroyed. The northern and eastern portions of the region also have been excluded from the primary target area. Desorption data from coal cores taken in these parts of the region indicate low gas contents, generally less than 50 cubic feet per ton.

In the western part of the target area 310 square miles have been identified as having the greatest potential for the initial development Of coalbed methane gas. Coal found in this area generally is higher in rank and found at greater depths (1,000 to 2,000 feet) than coal to the north, south and west. Desorption data for coal cores taken from this area indicate methane contents ranging from 75 to 490 cubic feet per ton and averaging approximately 250 cubic feet per ton.

Within the primary target area specific test sites can be defined based on localized structural controls (LANDSAT imagery), coalbed isopach maps, overburden isopach maps, and the occurrence of igneous intrusives. Structurally attractive areas include zones along fold axes where methane desorbed from coal can collect in place in the open fractures that developed in the stressed rocks, and at the intersections of two or more linear structural features. Zones where the rocks are stressed are attractive areas for methane accumulation only if a suitable means for trapping the gas is present, usually in the form of an impermeable cap rock. An initial program recommended for investigating the methane recovery potential within the Raton Mesa region includes:

1. Construction of a lineation map of the region, particularly in the primary target area, utilizing satellite imagery and aerial photographs.

2. Compilation and analyses of regional water well data to determine methane content of the effluent.

3. Review of all geophysical logs available in the upper 5,000 feet of the primary target area to analyze the stratigraphic distribution and cumulative thickness of coalbeds.

4. Enter into cooperative agreements with private operators or government agencies drilling in the primary target areas for the collection of coal core samples for desorption, and production testing of the coalbed interval.

5. Construction of coal isopach and overburden maps to outline coalbeds with a cumulative thickness exceeding 10 feet, and areas with greater than 1,000 feet of overburden. These maps would identify areas where significant amounts of in-place coalbed methane are likely to occur.

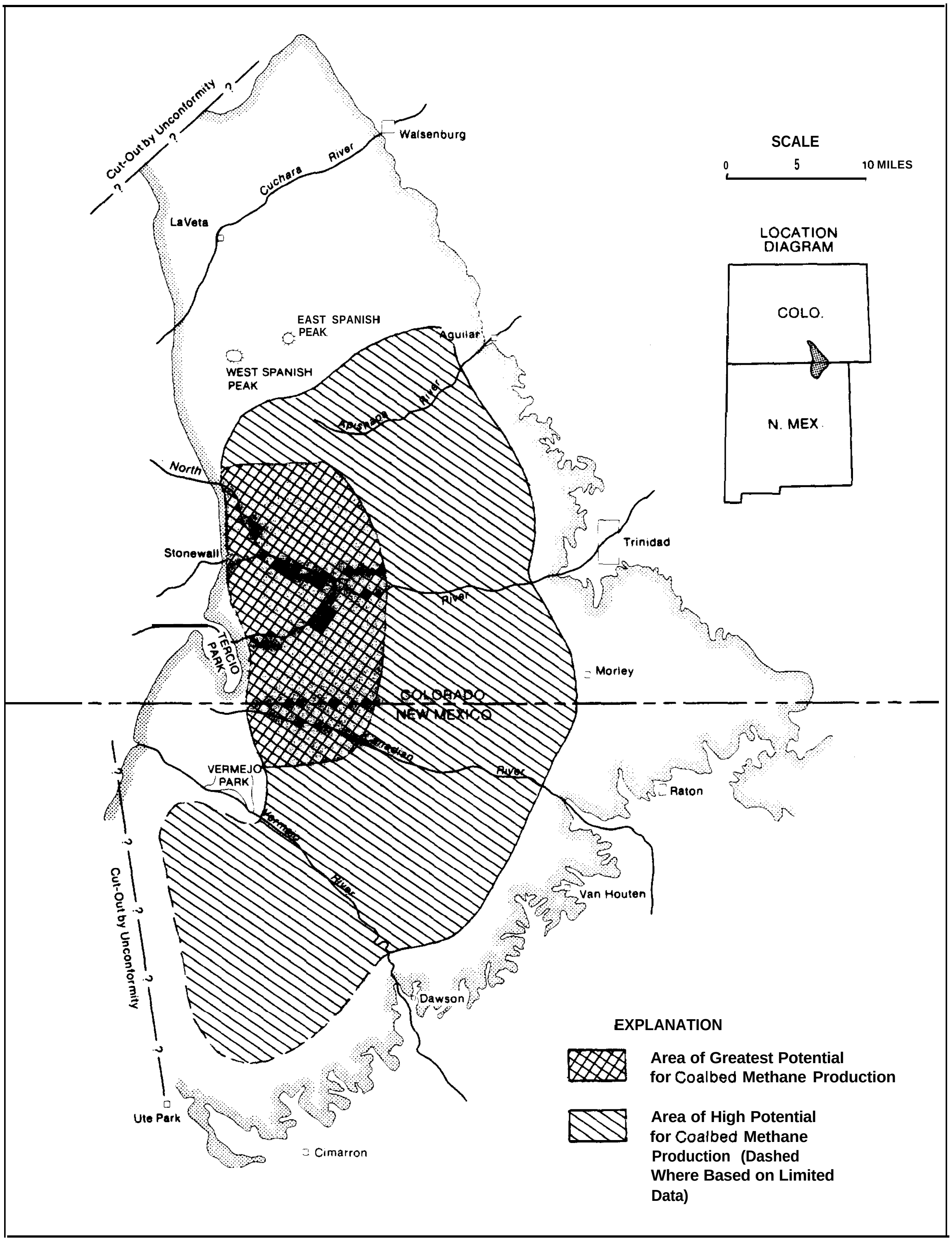


Figure 6-1. Redefined Target Area of the Raton Mesa Region

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Appendix A

A-1	Index to Topographical Maps of the United States at the Scale of 1:1,000,000
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B-1 Geologic Map Index of Colorado

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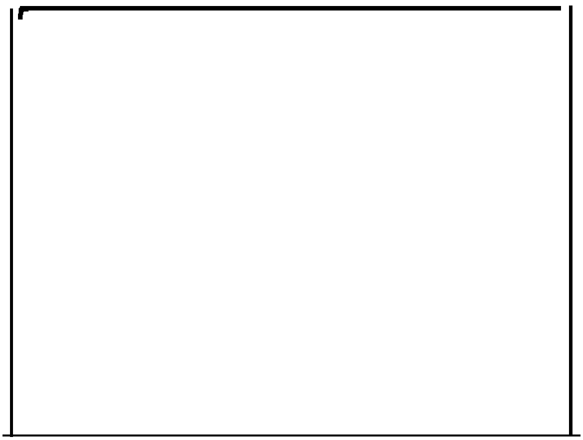
List of Geological Survey
Geologic and Water-Supply Reports and Yaps for

COLORADO



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U.S. DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGIC AND WATER-SUPPLY REPORTS AND MAPS

COLORADO

December 1977

This list contains reports and maps published by the Geological Survey relating to the geology and mineral and water resources of Colorado. A separate list of bibliographies and publications of general interest is available on request, as are a general catalog of Geological Survey publications (not including topographic maps), and State indexes to topographic mapping.

Bulletins, professional papers, water-supply papers, and other book reports for which a price is stated, including some that have gone out of print at the Government Printing Office, as indicated by an asterisk (*), are for sale by the BRANCH OF DISTRIBUTION, US. GEOLOGICAL SURVEY, 1200 SOUTH EADS STREET, ARLINGTON, VA 22202, and from the U.S. Geological Survey, Public Inquiries Offices: Federal Building, Room 1012, 1961 Stout Street, Denver, CO 80294; and Federal Building, Room 8102, 125 South State Street, Salt Lake City, UT 84138 (authorized agents of Superintendent of Documents). Prepayment is required and should be made by check or money order payable to the U.S. Geological Survey. Numerous libraries and educational institutions throughout the country are depositories for this material and a list of Colorado depositories is included.

Maps, folios, hydrologic atlases. and charts are sold by the Geological **Survey.** They may be purchased over the counter or ordered from the BRANCH OF DISTRIBUTION, U.S. GEOLOGICAL SURVEY, BLDG. 41, FEDERAL CENTER, DENVER, CO 80225. Remittances should be made by check or money order payable to U.S. Geological Survey. A discount of 30 percent is allowed on an order of $300 or more, based on the retail price. No other discount is applicable. Maps may also be purchased *over* the counter at the U.S. Geological Survey offices where books are sold, and at the Survey's Public Inquiries Offices: Geological Survey, National Center, Room 1C402, 12201 Sunrise Valley Drive, Reston, Va.; and General Services Building, Room 1028. 19th and F Streets, NW., Washington, D.C.

References to geologic information on Colorado may be obtained from the following Geological Survey publications: Geologic Man Index of Colorado., described herein, and from Bibliographies of North American Geology - Bulletins *746 (1785-1918), *747 (1785-1918), "823 (1919-28), *937 (1929-39), "985 (1950), *1025 (1951), *1035 (1952-53), *1049 (1940-49), *1054 (1954), *1065 (1955), *1075 (1956), *1095 (19571, *1115 (1958), *1145 (1959), * 1195 (1950-59) set of 4 volumes, *1196 (1960), "1197 (1961), *1232 (1962), *1233 (19631, *1234 (1964), '1235 (1965), 1266 (1966), $8.25, "1267 (19671, "1268 (1968), 1269 (1969) $11.35, and 1370 (1970) $8.70. Bibliographies and indexes of publications relating to ground water are Water-Supply Papers *992 (1879-1945), *1492 (1946-55), *1863 (1963), and * 1864 (1964). A water resources investigations folder, available free upon request to the Geological Survey, 420 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092, shows the location of stream-gaging stations, observation wells, quality-of-water sample collection sites, area1 hydrologic studies, average annual runoff, average discharge of principal streams, and availahility of ground water. A brief text lists the hydrologic network, the area1 and Statewide projects, and selected references, Additional information is obtainable from Assistant Director, Central Region, U.S. Geological Survey, Denver Federal Center, Denver, CC 80225, and Director and State Geologist, Colorado Geological Survey, 254 Columbine Bldg., Denver. CO 80203.

Information on altitudes in the United States is contained in Bulletins *5, *76, *160, "274, "689, *817, and *1212; information on boundaries and areas of the United States, with historical outlines of boundary changes, is contained in Bulletins "13, "171, *226, *302, *689, *817, "1212. and Professional Paper 909:, information on results of primary triangulation and primary traverse from 1894 to 1918 is contained in Bulletins *122, *181, * 201, "216, *245, "276, *310, *440, "'496, *551, "644, "709, and Parts 1 of the *18th, *19th, *20th, and * 21st Annual Reports. Further information on more recent triangulation, transit traverse, and spirit leveling in Colorado is obtainable upon specific request.

Current *Publications* are announced by means of monthly notices. "New Publications of the Geological Survey." Free on application to the Geological Survey, 329 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092.

ANNUAL REPORTS

*Second. 1880-80. 1882. Contains: Abstract of report on geology and mining industry of Leadville, Lake County, Colo., by S. F. Emmons. p. 201-290.

"Sixth, 1884-84. 1885. Contains: Mount Taylor and the Zuni Plateau, by C. E. Dutton. p. 105198.

*Eighth, 1886-87. 1889. Part 1 contains: The fossil butterflies of Florissant, Colo., by S. H. Scudder. p. 433-474.

*Ninth, 1887-88. 1889. Contains: On the geology and physiography of a portion of northwestern Colorado and adjacent parts of Utah and Wyoming. by C. A. White. p. 667-712.

"Thirteenth. 1891-92. 1892. Part 3 (18931 contains: Report upon the construction of topographic maps and the selection and survey of reservoir sites in the hydrographic basin of Arkansas River, Colo., by A. H. Thompson. p. 429-444.

"Fourteenth, 1892-93. 1893. Part 2 (1894) contains: The laccolithic mountain groups of Colorado, Utah, and Arizona, by Whitman Cross. p. 157-241.

"Sixteenth, 1894-95. 1896. Part 2 (1895) contains: Geology and mining industries of the Cripple Creek district, Colorado, by Whitman Cross and R. A. F. Penrose, Jr. p. 1-209; Water resources of a portion of the Great Plains, by Robert Hay. p. 535-588.

*Seventeenth. 1895-96. 1896. Part 2 contains: Geology of Silver Cliff and the Rosita Hills. Colo., by Whitman Cross. p. 263.403; The mines of Custer County, Colo., by S. F. Emmons. p. 405-472; The underground water of the Arkansas Valley in eastern Colorado, by G. K. Gilbert. p. 551-601.

*Eighteenth, 1896-97. 1897. Part 3 11898) contains: Preliminary report on the mining industries of the Telluride quadrangle, Colorado, by C. W. Purington. p. 745-850.

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*Twenty-first, 1899-1900. 1900. Part 2 contains: Geology of the Rico Mountains, Colo., by Whitman Cross and A. C. Spencer. p. 7-165. Part 4 (1901) contains: The High Plains and their utilization, by W. D. Johnson. p. 601-741. (See Twenty-second Annual Report.)

*Twenty-second, 1900-1901. 1901. Part 1 contains: The asphalt and bituminous rock deposits of the United States, by G. H. Eldridge. p. 209-452. Part 2 contains: The ore deposits of the Rico Mountains, Colo., by F. L. Ransome. p. 229-398. Part 3 (1902) contains: The Rocky Mountain coal fields, by L. S. Storrs. p. 415-471. Part 4 (1902) contains: The High Plains and their utilization (conclusion), by W. D. Johnson. p. 631.669.

(Beginning with the twenty-third (1901-2), the annual reports of the Geological Survey contain no technical papers but were published separately until 1933. Since 1933 a condensed form has been included in the annual report of the Secretary of the Interior. For the fiscal years 1936 to 1963, a limited number of copies of the report as it appeared in the annual report of the Secretary were reprinted separately for official use; copies of these may be had free by persons directly interested. insofar as they are in stock.1

MINERAL RESOURCES OF THE UNITED STATES

The annual volumes of Mineral Resources of the United States contain statistics of production by calendar years and matters relating to technology and resources. Some of the chapters deal with a particular mineral or group of minerals, but much of the information is statistical. These volumes are not listed. The volumes of Mineral Resources were issued by the Geological Survey for the years 1882 to 1923. Reports for 1924 and subsequent years are published by the Bureau of Mines, Washington, DC 20244. as Minerals Yearbooks.

MONOGRAPHS

*10. Dinocerata-A monograph of an extinct order of gigantic mammals, by 0. C. Marsh. 1866. 243 p.
"12. Geology and mining industry of Leadville, Colo., with atlas, by S. F. Emmons. 1886. 770 p. and atlas of 35 sheets folio.
*21. Tertiary rhynchophorous Coleoptera of the United States, by S. H. Scudder. 1893.206 p.
"27. Geology of the Denver Basin in Colorado, by S. F. Emmons, Whitman Cross, and G. E. Eldridge. 1896.
*31. Geology of the Aspen mining district, Colorado, with atlas, by J. E. Spurr. 1898. 260 p., and atlas of 30 sheets folio.
*35. The later extinct floras of North America, by J. S. Newberry. 1898. 295 p.
"40. Adephagous and clavicorn Coleoptera from the Tertiary deposits at Florissant, Colo., by S. H. Studder. 1900. 148 p.
*44. Pseudoceratites of the Cretaceous, by Alpheus Hyatt. 1903. 351 p.
*49. The Ceratopsia, by J. B. Hatcher. 1907.300 p.
"51. Cambrian Brachiopoda, by C. D. Walcott. 1912. In two parts. Part 1, 872 p.; part 2, 363 p.
*54. The Mesozoic and Cenozoic Echinodermata of the United States, by W. B. Clark and M. W. Twitchell. 1915. 341 p.

GEOLOGIC FOLIOS

*7. Pikes Peak, Colo., by Whitman Cross. 1894. 8 p., 5 maps.
*9. Anthracite-Crested Butte, Colo., by S. F. Emmons, Whitman Cross, and G. H. Eldridge. 1894. 11 p., 8 maps.
"36. Pueblo, Colo., by G. K. Gilbert. 1897. 9 p.. 5 maps.
*48. Tenmile district special, Colorado, by S. F. Emmons. 1898. 6 p., 4 maps.
*57. Telluride, Colo., by Whitman Cross and C. W. Purington. 1899. 19 p., 4 maps
"'58. Elmoro. Colo.. bv R. C. Hills. 1899. 6 p., 5 mans.
"60. La Plata, Colo., by Whitman Cross, A. C. Spencer, and C. W. Purington. 1899 (1901). 14 p., 4 maps.
"68. Walsenburg, Colo., by R. C. Hills, 1900. 6 p., 6 maps,
*71. Spanish Peaks, Colo., bv R. C. Hills. 1901. 7 p., 6 maps.
*120. Silverton, Colo.. by Whitman Cross, Ernest Howe, and F. L. Ransome. 1905. 34 p., 4 maps.
"131. Needle Mountains, Colo., by Whitman Cross, Ernest Howe, J. D. Irving, and W. H. Emmons. 1905. 14 p.. 4 maps.
'135. Nepesta. Colo., by C. A. Fisher. 1906. 6 p., 3 maps.
-153. Ouray. Colo., by Whitman Cross, Ernest Howe, and J. D. Irving. 1907.20 p., 3 maps.
*171. Engineer Mountain, Colo., by Whitman Cross, and A. D. Hole. 1910. 14 p., 3 maps.
'186. Apishapa. Colo.. by G. W. Stose. 1912. 12 p., 3 maps.
*198. Castle Rock, Colo., by G. B. Richardson. 1915. 14 p., 3 maps.
*203. Colorado Springs, Colo., by G. I. Finlay. 1916. 16 p., 5 maps.
*214. Raton-Brilliant-Koehler, N. Mex.-Colo., by W. T. Lee. 1922. 17 p.. 10 maps.

PROFESSIONAL PAPERS

*16. The Carboniferous formations and faunas of Colorado, by G. H. Girty. 1903. 546 p.
32. Preliminary report on the geology and underground water resources of the central Great Plains, by N. H. Darton. 1905. 433 p.

"52. Geology and underground waters of the Arkansas Valley in eastern Colorado, by N. H. Darton. 1906. 90 p.

"54. Geology and gold deposits of the Cripple Creek district, Colorado, by Waldeman Lindgren and F. L. Ransome. 1906. 516 p.

*63. Economic geology of the Georgetown quadrangle (together with the Empire district). Colorado, by J. E. Spurr and G. H. Garrey, with general geology, by S. H. Ball. 1908. 422 p.

"67. Landslides in the San Juan Mountains, Colo., including a consideration of their causes and their classification, by Ernest Howe. 1909. 58 p.

*75. Geology and ore deposits of the Breckenridge district, Colorado, by F. L. Ransome. 1911.187 p.

*90. Shorter contributions to general geology, 1914. 1915. Contains: Geology of the pitchblende ores of Colorado, by E. S. Bastin. p. 1-5; Dike rocks of the Apishapa quadrangle, Colorado, by Whitman Cross. p. 17-31; Contributions to the stratigraphy of southwestern Colorado, by Whitman Cross and E. S. Larsen. p. 39-50; The history of a portion of Yampa River, Colo., and its possible bearing on that of Green River, by E. T. Hancock. p. 183-189.

*94. Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colo., by E. S. Bastin and J. M. Hill. 1917. 379 p.

*95. Shorter contributions to general geology, 1915. 1916. Contains: Eocene glacial deposits in southwestern Colorado. bv W. W. Atwood. p. 13-26; Relation of the Cretaceous formations to the Rocky Mountains in Coloradoand New Mexico, by W. T. Lee. p. 27-58.

*98. Shorter contributions to general geology. 1916. 1917. Contains: The flora of the Fox Hills sandstone, by F. H. Knowlton. p. 85-93.

* 100. The coal fields of the United States. 1929. Contains: General introduction, by M. R. Campbell. p. 1-33. (Published in June 1917.)

* 101. Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico, by W. T. Lee and F. H. Knowlton. 1917 (1918). 450 p.

*120. Shorter contributions to general geology, 1918. 1919. Contains: Some American Cretaceous fish scales, with notes on the classification and distribution of Cretaceous fishes, by T. D. A. Cockerell. p. 165-206.

*130. The Laramie flora of the Denver Basin. with a review of the Laramie problem, by F. H. Knowlton. 1922. 175 p.

*131. Shorter contributions to general geology, 1922. 1923. Contains: Revision of the flora of the Green River formation. with descriptions of new species. by F. H. Knowlton. p. 133-182; Fossil plants from the Tertiary lake beds of south-central Colorado, by F. H. Knowlton. p. 183-197; The fauna of the so-called Dakota Formation of northern central Colorado and its equivalent in southeastern Wyoming, by J. B. Reeside, Jr. p. 199-212.

*132. Shorter contributions to general geology. 1923-24. 1925. Contains: Relations of the Wasatch and Green River Formations in northwestern Colorado and southern Wyoming, with notes on oil shale in the Green River Formation, by J. D. Sears and W. H. Bradley. p. 93-107.

*134. Upper Cretaceous and Tertiary formations of the western part of San Juan Basin, Colo., and N. Mex.. by J. B. Reeside. Jr.. and Flora of the Animas Formations, by F. H. Knowlton. 1924. 117 p.

*135. The composition of the river and lake waters of the United States, by F. W. Clarke. 1924. 199 p.

*138. Mining in Colorado-A history of discovery, development, and production, by C. W. Henderson. 1926. 263 p.

*148. Geology and ore deposits of the Leadville mining district, Colorado, by F. S. Emmons, J. D. Irving, and G. F. Loughlin. 1927. 368 p.

* 149. Correlation of geologic formations between east-central Colorado, central Wyoming, and southern Montana, by W. T. Lee. 1927. 80 p.

*151. The cephalopods of the Eagle sandstone and related formations in the Western Interior of the United States, by J. B. Reeside, Jr. 1927. 87 p.

*154. Shorter contributions to general geology, 1928. 1929. Contains: Algae reefs and oolites of the Green River Formation, by W. H. Bradley. p. 203-223; Additions to the flora of the Green River Formation, by R. W. Brown. p. 279-299.

*155. The flora of the Denver and associated Formations of Colorado, by F. H. Knowlton. 1930. 142 p.

*158. Shorter contributions to general geology, 1929. 1930. Contains: The occurrence and origin of analcite and meerschaum beds in the Green River Formation of Utah, Colorado, and Wyoming, by W. H. Bradley. p. 1-7; The contact of the Fox Hills and Lance Formations, by C. E. Dobbin and J. B. Reeside, Jr. p. 9-25; The varves and climate of the Green River epoch, by W. H. Bradley. p. 87-110.

* 166. Physiography and Quaternary geology of the San Juan Mountains, Colo., by W. W. Atwood and K. F. Mather. 1932. 176 p.

* 168. Origin and microfossils of the oil shale of the Green River Formation of Colorado and Utah, by W. H. Bradley. 1931. 58 p.

*169. Geology and ore deposits of the Bonanza mining district, Colorado, by W. S. Burbank, with a section on history and production, by C. W. Henderson. 1932. 166 p.

*176. Geology and ore deposits of the Breckenridge mining district, Colorado, by T. S. Lovering. 1934. 64 p.

*178. Geology and ore deposits of the Montezuma quadrangle, Colorado, by T. S. Lovering. 1935. 119 p.

* 183. Correlation of the Jurassic formation of parts of Utah, Arizona, New Mexico, and Colorado, by A. A. Baker, C. H. Dane, and J. B. Reeside, Jr. 1936. 66 p.

*185-B. Paleozoic formations of the Mosquito Range, Colo., by J. H. Johnson. 1934 (1935). p. 15-34.

*185-C. The recognizable species of the Green River flora, by R. W. Brown. 1934 (1935). p. 45-77.

*185-D. A flora of Pottsville age from the Mosquito Range, Colo., by C. B. Read. 1934. p. 79-96.

*185-I. Geomorphology of the north flank of the Uinta Mountains, by W. H. Bradley. 1936. p. 136-204.

*186-J. Additions to some fossil floras of the Western United States, by R. W. Brown. 1937. p. 163-206.

*186-K. The stratigraphy of the Upper Cretaceous rocks north of the Arkansas River in eastern Colorado, by C. H. Dane, W. G. Pierce, and J. B. Reeside, Jr. 1937. p. 207-232.

*189-I. Fossil plants from the Colgate member of the Fox Hills sandstone and adjacent strata, by R. W. Brown. 1939. p. 239-275.

*197-A. Alkalic rocks of Iron Hill, Gunnison County, Colo., by E. S. Larsen. 1942. p. A1-A64.

*219. Geology and ore deposits of the La Plata district, Colorado, by E. B. Eckel, with sections bv J. S. Williams. F. W. Galbraith. and others. 1949 (1950). 179 p.

*221-D. Cretaceous plants from southwestern Colorado, by R. W. Brown. 1950. p. 45-66.

*221-G. Pre-Wisconsin soil in the Rocky Mountain region-A progress report, by C. B. Hunt and V. P. Sokoloff. 1950. p. 109-123.

223. Geology and ore deposits of the Front Range, Colo., by T. S. Lovering and E. N. Goddard. 1950 (1951). 319 p. $9.50. (Reprint.)

*227. Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-44, by J. B. Hanley, E. W. Heinrich, and L. R. Page. 1950. 125 p.

'233-B. Molluscan fauna of the Morrison Formation, by Teng-Chien Yen, with a summary of the stratigraphy, by J. B. Reeside, Jr. 1952. p. 21-51.

*235. Geology and ore deposits of the west slope of the Mosquito Range, Colo., by C. H. Behre, Jr. 1953. 176 p.

*239. Scaphitoid cephalopods of the Colorado group, by W. A. Cobban. 1951 (1952). 42 p.

*245. Geology and ore deposits of the Boulder County tungsten district, Colorado, by T. S. Lovering and Ogden Tweto. 1953 (1954). 199 p.

*254-A. American Upper Cretaceous Echinoidea, by C. W. Cooke. 1953. p. Al-A44.

*254-B. Nonmarine mollusks of Late Cretaceous age from Wyoming, Utah, and Colorado, by Teng-Chien Yen. 1954. p. 45-66.

*258. Geology and petrology of the San Juan region, southwestern Colorado, by E. S. Larsen, Jr., and Whitman Cross. 1956. 303 p.

*265. Geology of the Quartz Creek pegmatite district, Gunnison County, Colo., by M. H. Staatz and A. F. Trites, Jr. 1955. 111 p.

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*272-D. Evaporation from the 17 Western States, by J. S. Meyers, with a section on Evaporation rates, by T. J. Nordenson, U.S. Weather Bureau. 1962. p.71-100.

'272-F. Methods to compute long-wave radiation from the atmosphere and reflected solar radiation from a water surface, by G. E. Koberg. 1964. p.107-136.

"'274-B. Dakota group in northern Front Range foothills, Colorado, by K. M. Waagé. 1955. p. 15-51.

*274-H. Palmlike plants from the Dolores Formation (Triassic), southwestern Colorado. by R. W. Brown. 1956. p. 205-209.

"274-M. Metamorphism and the origin of granitic rocks, Northgate district, Colorado, by T. A. Steven. 1957. p. 335-375.

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Information on water levels and artesian pressure in observation wells											
1935	* 777		1946	* 1075		1952	*1225		1966-70	* 1980	$2.35
1936	* 817		1947	*1100		1953	*1269				
1942	* 948		1948	*1130		1954	* 1326				
1943	* 990		1949	*1160		1955	* 1408				
1944	* 1020		1950	*1169		1956.60	* 1760				
1945	* 1027		1951	*119.5		1961-65	* 184R				

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Information on the quality of the suface water
("a" indicates data on quality of water for irrigation)

Year	WSP	Price
1941	'942	
1942	-950	
1943	*970	
1944	* 1022	
1945	* 1030	
1946	* 1050	
1947	'1102	
1948	'1133	
1949	*1163	
1950	*1189	
1951	* 1200	
(a)	*1264	
1952	* 1251	
	* 1252	
	'1253	
	'1362	
1953	'1291	
	'1292	
(a)	* 1293	
	* 1380	
1954	'1351	
	* 1352	

Year	WSP	Price
	'1353	
(a)	* 1430	
1955	*1401	
	• 1402	
	* 1403	
(a)	* 1465	
1956	'1451	
	*1452	
	* 1453	
(a)	* 1485	
1957	-1521	
	* 1522	
	'1523	
(a)	'1524	
1958	*1572	
	* 1573	
	'1574	
(a)	* 1575	
1959	* 1643	
	*1644	

Year	WSP	Price
1959	'1645	
(a)	* 1699	
1960	'1743	
	* 1744	
	* 1745	
(a)	*1746	
1961	*1883	
	*1884	
	*1885	
(a)	* 1886	
1962	* 1943	
	* 1944	
	* 1945	
	* 1946	
1963	* 1949	
	* 1950	
	'1951	
(a)	* 1952	
1964	* 1956	
	* 1957	
	* 1958	

Year	WSP	Price
1964(a)	* 1960	
1965	* 1963	
	'1964	
	* 1965	
(a)	* 1967	
1966	* 1993	
	*1994	
	*1995	
1967	'2013	
	2014	
	*2015	
1968	*2095	
	'2096	
	2097	$3.45
	* 2098	
1969	2145	3.25
	2146	3.85
	2147	4.00
	*2148	
1970	2150	3.50
	*2155	
	2157	4.50
	215.3	3.40

Stream measurements in the years mentioned

Year	WSP	Price
1897	'15	
	*16	
1898	*28	
1899	*37	
	*38	
1900	'49	
	'50	
1901	*66	
	*75	
1902	*84	
	*85	
1903	[illegible]	
	[illegible]	
1904	'131	
	'133	
1905	*172	
	* 173	
	*174	
	*175	
1906	'208	
	'209	
	*210	
	-211	
1907-e	*246	
	*247	
	*248	
	*249	
1909	'266	
	*267	
	*268	
	'269	
1910	'286	
	*287	
	* 288	
	*289	
1911	*306	
	*307	
	* 308	
	-309	
1912	"326	
	*327	
	*328	
	*329	
1913	'356	

Year	WSP	Price
	*357	
	*358	
	'359	
1914	'386	
	'387	
1915	'406	
	*407	
1916	*436	
	*437	
	-439	
1917	'456	
	'457	
	*459	
1918	* 476	
	'477	
	*479	
1919.20	'506	
	-507	
	*509	
1921	*526	
	*527	
	'529	
1922	* 546	
	'547	
	"549	
1923	-566	
	* 567	
	'569	
1924	*586	
	'587	
	'589	
1925	* 606	
	'607	
	*608	
	* 609	
1926	*626	
	'627	
	*628	
	*629	
1927	*646	
	*647	
	* 643	

Year	WSP	Price
192x	'666	
	*667	
	'669	
1929	*686	
	*689	
1930	*701	
	'702	
	*704	
1931	'716	
	*719	
1932	*731	
	*733	
	'734	
1933	*746	
	*749	
1934	*761	
	*762	
	*763	
	'764	
1935	*786	
	* 787	
	*788	
	*789	
1936	'806	
	*807	
	* 808	
	*809	
1937	*826	
	*827	
	*828	
	'829	
1938	*856	
	*857	
	*858	
	*859	
1939	*876	
	*877	
	*878	
	*879	
1940	*896	
	*897	
	*898	
	'899	
1941	'926	

Year	WSP	Price
	-927	
	*928	
	'929	
1942		
	*957	
	'958	
	'959	
1943	'976	
	*977	
	*978	
	*979	
1944	*1006	
	'1007	
	*1008	
	* 1009	
1945	* 1036	
	*1037	
	* 1038	
	* 1039	
1946	* 1056	
	*1057	
	* 1058	
	"1059	
1947	*1086	
	*1087	
	*1088	
	*1089	
1948	*1116	
	*1117	
	'1118	
	'1119	
1949	-1146	
	*1147	
	-1148	
	*1149	
1950	*1176	
	*1177	
	*1178	
	*1179	
1951	'1210	
	'1211	
	*1212	
	'1213	
1952	*1240	

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Year	WSP	Price	Year	WSP	Price	Year	WSP	Price	Year	WSP	Price
Stream measurements in the years mentioned-Continued											
	*1241		1955	*1391			* 1561			*1919	
	'1242			* 1392			*1562			*1921	
	* 1243			* 1393			*1563			*1923	
1963	* 1280		1956	* 1440		1959	* 1630		1961-65	* 1924	
	* 1281			*1441			*1631			* 1925	
	*1282			* 1442			'1632		1966.70	2118	$5.65
	*1283			*1443		1959	* 1633			*2119	
1954	* 1340		1957	'1510		1960	*1710			'2121	6 15
	*1341			'1511			*1711			'2123	5.70
	'1342		1957	*1512			*1712			*2124	
	*1343			*1513			*1713			2125	4 40
1955	*1390		1958	* 1560		1961-65	*1918				

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645. A procedure for evaluating environmental impact, by L. B. Leopold, F. E. Clark, B. B. Hanshaw, and J. R. Balsley. 1971. 13 p. (Reprint.1

656. Index of surface-water records to September 30, 1970—Part 6, Missouri River Basin. 1971. 71 p.

657. Index of surface-water records to September 30, 1970—Part 7, lower Mississippi River basin. 1972. 67 p.

658. Index of surface-water records to September 30, 1970—Part 8, Western Gulf of Mexico basins. 1971. 53 p.

659. Index of surface-water records to September 30, 1970—Part 9, Colorado River basin. 1971. 55 p.

675. Bibliography of the geology of the Green River Formation, Colo., Utah, and Wyo., to March 1, 1973, by M. C. Mullens. 1973. 20 p.

676. Estimated use of water in the United States in 1970, by C. R. Murray and E. B. Reeves. 1972. 37 p.

682. Summary of United States mineral resources, by D. A. Brobst, W. P. Pratt, and V. E. McKelvey. 1973. 19 p.

689. Effects of the May 5-6, 1973, storm in the Greater Denver area, Colorado, by W. R. Hansen. 1973. 20 p.

698. Mineral resources: potentials and problems, by W. P. Pratt and D. A. Brobst. 1974.20 p.

701. Goals, strategy, and tasks of the earthquake hazard reduction program, by R. E. Wallace. 1974. 26 p. (Reprinted 1976.)

704. Molybdenite in the Montezuma district of central Colorado, by G. J. Neuerburg, Theodore Botinelly, and J. R. Watterson. 1974. 21 p.

713. Seismic engineering program report, October-December 1974. 1974. 19 p.

715-E. Selection of streamflow and reservoir-release models for river-quality assessment, by M. E. Jennings, J. 0. Shearman, and D. P. Bauer. 1976. p. El-E12.

717-A. Seismic engineering program report, January-March 1975. 1975. 17 p.

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717-C. Seismic engineering program report, July-September 1975. 1976. 17 p.

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723-A. Earthquakes in the United States, January-March 1974, by C. W. Stover, R. B. Simon, and W. J. Person. 1976. p. A1-A18.

723-B. Earthquakes in the United States, April-June 1974, by R. B. Simon, C. W. Stover, and W. J. Person. 1976. p. Bl-B24.

723-C. Earthquakes in the United States, July-September 1974, by C. W. Stover, R. B. Simon, and W. J. Person. 1976. p. C1-C19.

CIRCULARS-Continued

723-D. Earthquakes in the United States, October-December 1974. by C. W. Stover, R. B. Simon, and W. J. Person. 1976. p. Dl-D27.

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731. A guide to State programs for the reclamation of surface mined areas, by E. A. Imhoff. T. 0. Friz. and J. R. LaFevers, 1976. 33 p.

736-A. Seismic engineering program report, January-March 1976. 17 p.

736-B. Seismic engineering program report, April-June 1976. 12 p.

736-C. Seismic engineering program report, July-September 1976. 1976 (1977). 14 p.

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742. Bibliography and index of U.S. Geological Survey publications relating to coal, 197 1-1975. by F. K. Walker. 1976. 32 p. (Supersedes Circular 709 and is a supplement to Bulletin 13771.

744. Research by the U. S. Geological Survey on organic materials in water, by R. A. Baker. 1976 (1977). 6 p.

745. Water consumption by nuclear powerplants and some hydrological implications, by E. V. Giusti and E. L. Meyer. 1977 14 p.

749-A Earthquakes in the United States, January-March 1975, by R. B. Simon, C. W. Stover. and W. J. Person. 1977. p.A1-A35.

749-B. Earthquakes in the United States, April-June 1975. by W. J. Person, R. B. Simon, and C. W. Stover. 1977. p.B1-B27.

749-C. Earthquakes in the United States, July-September 1975, by C. W. Stover, R. B. Simon, W. J. Person, and J. H. Minsch. 1977. p.C1-C29.

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753. Short papers of the U.S. Geological Survey Uranium-Thorium Symposium, 1977, edited by J. A. Campbell. 1977. 75 p. (Reprint.)

754. Bibliography of the geology of the Green River Formation, Colorado. Utah, and Wyoming, to March 1, 1977, by M. C. Mullens. 1977. 52 p.

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763. Progress report on selected geophysical activities of the United States, 1973-76---A quadrennium of cooperation and progress, edited by J. N. Jordan and K. L. Svendsen. 1977. 37 p.

765. Estimated use of water in the United States in 1975, by C. R. Murray and E. B. Reeves. 1977. 39 p.

767. Current oil and gas production from North American Upper Cretaceous chalks. by P. A. Scholle. 1977 51 p.

MAPS, CHARTS, AND ATLASES

(See ordering instructions on p. 1)

*BOULDER COUNTY, TUNGSTEN DISTRICT, COLORADO, by T. s. Lovering, E. B. Erkel. and Ogden Tweto. 1942:

*Beaver Creek area.

*Nederland area.

COAL INVESTIGATIONS MAPS

"Geology of the Paonia coal field, Delta and Gunnison Counties, Colo., by V. H. Johnson. 1948. Scale 1:48,000.

*C-4. Geology and coal resources of the Stonewall-Tercio area, Las Animas County, Colo., by G. H. Wood, R. B. Johnson, and others. 1951. Scale 1:31,680. 2 sheets.

C-20. Coal resources of the La Veta area, Huerfano County, Colo., by R. B. Johnson and J. G. Stephens. 1954. Scale 1:31,680. $1.25.

C-26. Geology and coal resources of the Gulnare, Cuchara Pass, and Stonewall area, Huerfano and Las Animas Counties, Colo., by G. H. Wood, Jr., R. B. Johnson, and G. H. Dixon. 1956. Scale 1:31,680. 2 sheets. $2.75 per set.

COAL FIELDS OF THE UNITED STATES (EXCLUDING ALASKA AND HAWAII). Sheet 1, by James Trumbull. 1959 (1960). Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 37 by 52 inches. $2.25 (Reprinted 1977.1

***COLORADO GEOLOGIC MAP, by** W. S. Burbank, T. S. Lovering, E. N. Goddard, and E. B. Eckel. 1935. Scale 1:500,000. This map has been reprinted (1975) and is available from the Colorado Geologic Survey, 1845 Sherman Street, Denver, CO 80203. Price $5 over the counter. $6.50 by mail.

***CORRELATION CHART OF COLORADO.** Tentative correlation of the named geologic units. by M. G. Wilmarth. 1931. 3 sheets. 10¢ per set.

DENVER MOUNTAIN AREA, COLORADO, Covers an area of about 5,700 square miles north and west of Denver, including Rocky Mountain National Park and the Denver Mountain Parks. Text on the reverse side of the map discusses the geology and history of the region, by Ogden Tweto. 1950. Lat 39" 30' to 40°45', long 104" 45' to 106°. Scale 1:190,000. Also published in a shaded relief edition. $1 each.

DINOSAUR NATIONAL MONUMENT, UTAH-COLO. 1951. Contains brieftext on history of exploration and mapping of area and describes the topography, rock formations, and ancient and present-day flora and fauna, with illustrations. Includes a generalized columnar section of the rocks exposed. Scale 1:62,5000. $2. Also published in a shaded relief edition, $2.

***GEOLOGIC MAP OF THE FRONT RANGE MINERAL BELT, COLORADO,** by T. S. Lovering and E. N. Goddard. 1950 (1951). Scale 1:62,5000. 2 sheets. (Issued as plate 2 of Professional Paper 223.)

GEOLOGIC MAP OF THE UNITED STATES. Scale 1:2,500,000. $5.

***GEOLOGIC MAP INDEX OF COLORADO,** by Leona Boardman. 1954. Shows by colored outlines areas in Colorado for which geologic maps have been published and locates many mine maps that show local geology. A text printed on margin of sheet gives the scale. data, author, and sources of publication of each geologic map. Scale 1:750,000.

GEOLOGIC MAP INDEX OF COLORADO, PART B, 1953-69, compiled by W. L. McIntosh and M. F. Eister. 1972. Lat 37' to 41°, long 102" to 109". Scale 1:1,000,000 (1 inch **about** 16 miles.) 50¢.

GEOTHERMAL GRADIENT MAP OF NORTH AMERICA, by the Geothermal Survey of North America Subcommittee of the American Association of Petroleum Geologists' Research Committee. 1976. Scale 1:5,000,000. Two sheets. $4 per set.

SUBSURFACE TEMPERATURE MAP OF NORTH AMERICA, by the Geothermal Survey of North America Subcommittee of the Association of Petroleum Geologists' Research Committee. 1976. Scale 1:5,000,000. Two sheets. $4 per set.

***VEINS, FAULTS AND MINES OF THE FRONT RANGE MINERAL BELT, COLORADO,** by T.S. Lovering and E.N. Goddard. 1950 (1951). Scale 1:62,500. (Issued as **plate 3** of Professional Paper 223.)

GEOLOGIC QUADRANGLE MAPS: Scale 1:24,000, except as indicated; $1.75 each, except as indicated.(The corresponding maps bearing the prefix MF in the Minerals Investigations series are preliminary maps printed in black and white.)

GQ-33. Bull Canyon, Colo. Geology, by F. W. Cater, Jr. 1954. Lat 38" 07'39" to 38" 15', long 108" 45' to 108" 52'30".

GQ-55. Gateway, Colo. Geology, by F. W. Cater, Jr. 1975. Lat 38" 37'30" to 38" 45', long 108" 52'30" to 109".

GQ-57. Atkinson Creek, Colo. Geology, by E. F. McKay. 1955. Lat 38" 22'30" to 38" 30', long 108" 37'30" to 108" 45'. (See Map MF-18.)

GQ-58. Red Canyon, Colo. Geology, by E. J. McKay 1955. Lat 38" 22'30" to 38" 30', long 108" 45' to 108" 52'30". (See Map MF-17.)

GQ-59. Gypsum Gap. Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" to 38" 07'30", long 108" 37'30" to 108" 45'. (See Map MF-19.)

GQ-60. Pine Mountain, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" 37'30" to 38" 45', long 108" 45' to 108" 52'30". (See Map MF-20.)

GQ-61. Calamity Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" 30' to 38°37'30", long 108" 45' to 108" 52'30". (See Map MF-32.)

GQ-64. Horse Range Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38" to 38" 07'30", long 108" 52'30" to 109". (See Map MF-29.)

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-65. Naturita NW, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15′, long 108” 37’30” to 108” 45’. (See Map MF-30.)

GQ-66. Joe Davis Hill, Colo. Geology, by F. W. Cater, Jr, 1955. Lat 37” 52’30” to 38°, long 108” 45’ to 108” 52’30”. (See Map MF-27.)

GQ-68. Egnar, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 52’30” to 109”. (See Map MF-26.)

GQ-69. Hamm Canyon, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” to 38” 07′30″, long 108” 45’ to 108” 52’30”. (See Map MF-21.)

GQ-71. Davis Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. Lat 38” 15’ to 38” 22′30″, long 108° 45’ to 108” 52’30”. (See Map MF-31.)

GQ-72. Paradox, Colo. Geology. by C. F. Withington. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 52’30” to 109”. (See Map MF-22.)

GQ-77. Anderson Mesa, Colo. Geology, by F. W. Cater, Jr. 1955. (1956). Lat 38” 07’30” to 38” 15′, long 108” 52’30” to 109”. (See Map MF-25.)

GQ-78. Uravan, Colo. Geology, by F. W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 37’30” to 108” 45′, (See Map MF-24.)

GQ-81. Juanita Arch, Colo. Geology, by E. M. Shoemaker. 1955. Lat 38” 30’ to 38” 37′30″, long 108” 52’30” to 109”. (See Map MF-28.)

GQ-83. Rock Creek, Colo. Geology, by E. M. Shoemaker. 1956. Lat 38” 22’30” to 38” 30′, long 108° 52’30” to 109” (See Map MF-23.)

GQ-103. Golden, Colo. Bedrock geology, by Richard Van Horn. 1957. Lat 39” 45’ to 39 52′30″, long 105” 07’30” to 105” 15’.

GQ-151. Louisville, Colo. Bedrock geology, by F. D. Spencer. 1961. Lat 39” 52’30” to 40°, long 105” 07’30” to 105” 15’.

GQ-152. Ouray, Colo. Geology, by R. G. Luedke and W. S. Burbank. 1962. Lat 38” to 38” 07′30″, long 107” 37’30” to 107” 45’.

GQ-267. Geology of the Central City quadrangle, Colorado, by P. K. Sims. 1964. Lat 39” 45’ to 39” 52′30″, long 105” 30’ to 105” 37’30”.

GQ-291. Geology of the Ironton quadrangle, Colorado, by W. S. Burbank and R. G. Luedke. 1964. Lat 37” 52’30” to 38”. long 107” 37’30” to 107” 45’.

GQ-397. Geologic map of the Fort Lupton quadrangle, Weld and Adams Counties, Colo., by P. E. Soister. 1952. Lat 40” to 40” 07′30″, long 104” 45’ to 104” 52’30”.

GQ-398. Geologic map of the Hudson quadrangle, Weld and Adams Counties, Colo., by P. E. Soister. 1965. Lat 40° to 40° 07′30″, long 104° 37’30” to 104” 45’.

GQ-399. Geologic map of the Platteville quadrangle, Weld County, Colo., by P. E. Soister. 1965. Lat 40” 07’30” to 40° 15’. long 104° 45’ to 104” 52’30”.

GQ-486. Geologic map of the Cerro Summit quadrangle, Montrose County, Colo., by R. G. Dickinson. 1965 (1966). Lat 38” 22’30” to 38” 30′, long 107” 37’30” to 107” 45’.

GQ-504. Geologic map of the Telluride quadrangle, southwestern Colorado, by W. S. Burbank and R. G. Luedke. 1966. Lat 37” 52’30” to 38”. long 107” 45’ to 107” 52’30”.

GQ-511. Geologic map of the Marcellina Mountain quadrangle, Gunnison County, Colo., by D. L. Gaskill and L. H. Godwin. 1966. Lat 38” 52’30” to 39°, long 107” 07’30” to 107” 15’.

GQ-512. Geologic map of the Marble quadrangle, Gunnison and Pitkin Counties, Colo., by D. L. Gaskill and L. H. Godwin. 1966. Lat 39” to 39” 07′30″, long 107” 07’30” to 107” 15’.

GQ-536. Geologic map of the Dolores Peak quadrangle, Dolores and San Miguel Counties, Colo., by A. L. Bush and C. S. Bromfield. 1966, Lat 37” 45’ to 37” 52′30″, long 108” to 108” 07’30”.

GQ-578. Geologic map of the Oh-be-joyful quadrangle, Gunnison County, Colo., by D. L. Gaskill, L. H. Godwin, and F. E. Mutschler. 1967. Lat 38” 52’30” to 39°, long 107” to 107” 07’30”.

GQ-596. Geologic map of the Mount Tyndall quadrangle, Custer County, Colo., by M. R. Brock and Q. D. Singewald. 1968. Lat 38” 07’30” to 38” 15′, long 105” 15’ to 105” 22’30”. 2 sheets. Accompanied by 5-page text.

GQ-631. Geologic map of the Bristol Head quadrangle, Mineral and Hinsdale Counties, Colo., by T. A. Steven. 1967. Lat 37” 45’ to 38°, long 107” to 107” 15’. Scale 1:62,500.

GQ-702. Geologic map of the Elk Springs quadrangle, Moffat County, Colo., by J. R. Dyni. 1968. Lat 40° 15’ to 40° 30′, long 108” 15’ to 108” 30’. Scale 1:62,500.

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-703. Geologic map of the Banty Point quadrangle, Rio Blanco County, Colo., by H. L. Cullins. 1968. Lat 40” to 40” 07′30″, long 108” 52’30” to 109”.

GQ-704. Geologic map of the Chair Mountain quadrangle, Gunnison and Pitkin Counties, Colo., by L. H. Godwin. 1968. Lat 39” to 39” 07′30″, long 107” 15’ to 107” 22’30”.

GQ-725. Geologic map of the Hanover NW quadrangle, El Paso County, Colo., by P. E. Soister. 1968. Lat 38” 37’30” to 38” 45′, long 104” 22’30” to 104” 30’.

GQ-747. Geologic map of the Black Ridge quadrangle, Delta and Montrose Counties, Colo., by W. R. Hansen. 1968. Lat 38” 37’30” to 38” 45′, long 107” 45’ to 107” 52’30”.

GQ-783. Geologic map of the Corral Bluffs quadrangle, El Paso County, Colo., by P. E. Soister. 1968. Lat 38” 45’ to 38” 52’30”. long 104” 30’ to 104” 37’30”.

GQ-788. Geologic map of the Maroon Bells quadrangle, Pitkin and Gunnison Counties, Colo., by Bruce Bryant. 1969. Lat 39” to 39” 07′30″, long 106” 52’30” to 107”.

GQ-797. Geologic map of the Rico quadrangle, Dolores and Montezuma Counties, Colo., by W. P. Pratt, E. T. McKnight, and R. A. DeHon. 1969. Lat 37” 37’30” to 37” 45′, long 108” to 108” 07’30”.

GQ-812. Geologic map of the Black Cabin Gulch quadrangle, Rio Blanco County, Colo., by W. B. Cashion. 1969. Lat 39° 45’ to 39° 52′30″, long 108” 30’ to 108” 37’30”.

GQ-823. Geologic map of the Casa Grande quadrangle, Colfax County, N. Mex., and Las Animas County, Colo., by C. L. Pillmore. 1969 (1970). Lat 36” 45’ to 37°, long 104” 45’ to 105”. Scale 1:62,500.

GQ-829. Geologic map of the Drake quadrangle, Larimer County, Colo., by W. A. Braddock, Prinya Nutalaya, S. J. Gawarecki, and G. C. Curtin. 1970. Lat 40° 22’30” to 40” 30′, long 105” 15’ to 105” 22’30”.

GQ-832. Geologic map of the Masonville quadrangle, Larimer County, Colo., by W. A. Braddock, R. H. Calvert, S. J. Gawarecki, and Prinya Nutalaya. 1970. Lat 40” 22’30” to 40” 30′, long 105” 07’30” to 105” 15’.

GQ-833. Geologic map of the Nederland quadrangle, Boulder and Gilpin Counties, Colo., by D. J. Gable. 1969 (1970). Lat 39° 52’30” to 40°, long 105” 30’ to 105” 37’30”.

GQ-835. Geologic map of the Mellen Hill quadrangle, Rio Blanco and Moffat Counties, Colo., by H. L. Cullins. 1969 (1970). Lat 40” 07’30” to 49” 15′, long 108” 52’30” to 109”.

GQ-853. Geologic map of the Snowmass Mountain quadrangle, Pitkin and Gunnison Counties, Colo., by F. E. Mutschler. 1970. Lat 39” to 39” 07’30”. long 107” to 107” 07’30”.

GQ-863. Geologic map of the Hayden Peak quadrangle, Pitkin and Gunnison Counties, Colo., by Bruce Bryant. 1970. Lat 39° to 39” 07′30″, long 106” 45’ to 106” 52’30”.

GQ-875. Geologic map of the Peoria quadrangle, Arapahoe and Adams Counties, Colo., by P. E. Soister. 1972. Lat 39” 37’30” to 39” 45′, long 104” to 104” 07’30”.

GQ-903. Geologic map of the Rangely quadrangle, Rio Blanco County, Colo., by H. L. Cullins. 1971. Lat 40” to 40” 07′30″, long 108” 45’ to 108” 52′30″.

GQ-932. Geologic map of the Highland Peak quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 52’30” to 107”.

GQ-933. Geologic map of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1971. Lat 39° 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”.

GQ-952. Geologic map of the Mount Harvard quadrangle, Chaffee and Gunnison Counties, Colo., by M. R. Brock and Fred Barker. 1972. Lat 38” 45’ to 39°, long 106” 15’ to 106” 30’. Scale 1:62,500.

GQ-967. Geologic map of the Woody Creek quadrangle, Pitkin and Eagle Counties, Colo.. by V. L. Freeman. 1972. Lat 39° 15’ to 39” 22′30″, long 106” 52’50” to 107”.

GQ-978. Geologic map of the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1972. Lat 39° 52’30” to 40°, long 105” 22’30” to 105” 30’.

GQ-1001. Geologic map of the Red Creek Ranch quadrangle, Wyoming, Utah, and Colorado, by H. W. Roehler. 1972. Lat 41” to 41” 07′30″, long 109” to 109” 07’30”.

GQ-1002. Geologic map of the Four J Rim quadrangle, Sweetwater County, Wyo., and Moffat County, Colo., by H. W. Roehler. 1972. Lat 41” to 41” 07′30″, long 108” 52’30” to 109”.

GQ-1004. Geologic map of the Ruedi quadrangle, Pitkin and Eagle Counties, Colo., by V. L. Freeman. 1972. Lat 39” 15’ to 39” 22′30″, long 106” 45’ to 106” 52’30”.

GQ-1011. Geologic map of the Wetterhorn Peak quadrangle, Colorado, by R. G. Luedke. 1972. Lat 38” to 38” 07′30″, long 107” 30’ to 107° 37’30”.

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-1018. Geologic map of the Brushy Point quadrangle, Rio Blanco and Garfield Counties, Colo., by H. W. Roehler. 1972. Lat 39” 37’30” to 39” 45′, long 108” 37’30” to 108” 45’.

GQ-1019. Geologic map of the Razorback Ridge quadrangle, Rio Blanco and Garfield Counties, Colo., by H. W. Roehler. 1972. Lat 39” 37’30” to 39” 45′, long 108” 30’ to 108” 37’30”.

GQ-1052. Geologic map of the Spar City quadrangle, Mineral County, Colo., by T. A. Steven and P. W. Lipman. 1973. Lat 37” 30’ to 37” 45′, long 106° 45’ to 107”. Scale 1:62,500.

GQ-1053. Geologic map of the Creede quadrangle, Mineral and Saguache Counties, Colo., by T. A. Steven and J. C. Ratte. 1973. Lat 37” 45’ to 38°, long 106” 45’ to 107”. Scale 1:62,500.

GQ-1070. Geologic map of the Carpenter Ridge quadrangle, Gunnison County, Colo., by D. C. Hedlund and J. C. Olson. 1973 (1974). Lat 38” 22’30” to 38” 30′, long 107” 07’30” to 107” 15’.

GQ-1071. Geologic map of the Gateview quadrangle, Gunnison County, Colo., by J. C. Olson and D. C. Hedlund. 1973 (1974). Lat 38” 15’ to 38” 22′30″, long 107” 07’30” to 107” 15’.

GQ-1073. Geologic map of the Indian Hills quadrangle, Jefferson County, Colo., by Bruce Bryant, R. D. Miller, and G. R. Scott. 1973 (1974). Lat 39° 30’ to 39° 37′30″, long 105” 07’30” to 105” 15’.

GQ-1086. Geologic map of the Calf Canyon quadrangle, Garfield County, Colo., by H. W. Roehler. 1973 (1974). Lat 39” 30’ to 39” 37′30″, long 108” 37’30” to 108” 45’.

GQ-1113. Geologic map of the Henderson Ridge quadrangle, Garfield County, Colo., by H. W. Roehler. 1973 (1974). Lat 39” 30’ to 39” 37′30″, long 108” 30’ to 108” 37’30”.

GQ-1115. Geologic map of the Kremmling quadrangle, Grand County, Colo., by G. A. Izett and C. S. V. Barclay. 1973 (1975). Lat 40° to 40° 15’. lonn 106° 15’ to 106” 30’. Scale 1:62,500.

GQ-1131. Geologic map of the Smizer Gulch quadrangle, Rio Blanco and Moffat Counties, Colo., by W. J. Hail, Jr. 1973 (1974). Lat 40° 07’30” to 40° 15′, long 108” 15’ to 108” 22’30”.

GQ-1134. Geologic map of the Iris NW quadrangle, Gunnison and Saguache Counties, Colo., by D. C. Hedlund and J. C. Olson. 1974. Lat 38” 22’30” to 38” 30′, long 106” 52’30” to 107”.

GQ-1144. Geologic map of the Lone Mountain quadrangle, Moffat County, Colo., by E. J. McKay. 1974. Lat 40° 30’ to 40” 45′, long 108” 15’ to 108” 30’. Scale 1:62,500.

GQ-1145. Geologic map of the Maybell quadrangle, Moffat County, Colo., by E. J. McKay and M. J. Bergin. 1974. Lat 40” 30’ to 40° 45′, long 108” to 108” 15’. Scale 1:62,500.

GQ-1153. Geologic map of the Big Mesa quadrangle, Gunnison County, Colo., by D. C. Hedlund. 1974 (1975). Lat 38” 22’30” to 38” 30’. lone 107” to 107” 07’30”.

GQ-1156. Geologic map of the Trail Mountain quadrangle,-Grand County, Colo., by G. A. Izett. 1974. Lat 40° 07’30” to 40° 15’. long 105” 52’30” to 106”.

GQ-1166. Geologic map of the Scrivner Butte quadrangle, Sweetwater County, Wyo., and Moffat County, Colo., by H. W. Roehler. 1974. Lat 41” to 41” 07′30″, long 108” 45’ to 108” 52’30”.

GQ-1177. Geologic map of the Rudolph Hill quadrangle, Gunnison, Hinsdale, and Saguache Counties, Colo., by J. C. Olson. 1974. (1975). Lat 38” 07’30” to 38” 15′, long 107” to 107” 07’30”. Scale 1:24,000. Paleotopographic-contour interval 100 feet.

GQ-1178. Geologic map of the Powderhorn quadrangle, Gunnison and Saguache Counties, Colo., by D. C. Hedlund and J. C. Olson. 1975. Lat 38” 15’ to 38” 22′30″, long 107” to 107” 07’30”. Scale 1:24,000. Paleotopographic-contour interval 100 feet.

GQ-1195. Geologic map of the Rough Gulch quadrangle, Rio Blanco and Moffat Counties, Colo., by W. J. Hail, Jr. 1974 (1975). Lat 40” 07’30” to 40” 15′, long 108” 22’30” to 108” 30’. Scale 1:24,000. Structure-contour intervals 100 and 500 feet.

GQ-1224. Geologic map of the Bottle Pass quadrangle, Grand County, Colo., by R. B. Taylor. 1975. Lat 39° 52’30” to 40°, long 105” 52’30” to 106”. Scale 1:24,000.

GQ-1229. Geologic map of the Niwot quadrangle, Boulder County, Colo., by D. E. Trimble. 1975. Lat 40” to 40” 07′30″, long 105” 07’30” to 105” 15’. Scale 1:24,000. (Supersedes OF 74-10).

GEOLOGIC QUADRANGLE MAPS-Continued

GQ-1248. Geologic map of the Black Hawk quadrangle, Gilpin, Jefferson, and Clear Creek Counties, Colorado, by R. B. Taylor. 1976. Lat 39” 45’ to 39” 52'30", long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet) Sheet 32 by 40 inches.

GQ-1277. Geologic map of the Ward quadrangle, Boulder County, Colo., by D. J. Gable and R. F. Madole. 1976. Lat 40” to 40° 07'30", long 105” 30’ to 105” 37’30”. Scale 1:24,000.

GQ-1286. Geologic map of the Iris quadrangle, Gunnison and Saguache Counties, Colo., by J. C. Olson. 1976. Lat 38” 22’30” to 38” 30', long 106” 45’ to 106” 52’ 30”. Scale 1:24,000. (Supersedes Open-File 75-63.)

GQ-1287. Geologic map of the Houston Gulch quadrangle, Gunnison and Saguache Counties, Colorado, by J. C. Olson. 1976, Lat 38” 22’30” to 38” 30', long 106” 37’30” to 106” 45’. Scale 1:24,000. (Supersedes Open-tile 75-62.)

GQ-1323. Geologic map of the Big Narrows quadrangle, Larimer County, Colorado, by J. T. Abbott. 1976. Lat 40” 37’30” to 40° 45', long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet) Sheet 3” by 34 inches.

GQ-1337. Geologic map of the Sq..w Pass quadrangle, Clear Creek, Jefferson, and Gilpin Counties. Colorado, by D. M. Sheridan and S. P. Marsh. 1976 (1977). Lat 39” 37’30” to 39” 45’. long 105” 22’30” to 105” 30’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 42 inches.

GQ-1343. Geologic map of the Milligan Lakes quadrangle, Park County, Colorado, by D. G. Wyant and Fred Barker. 1976 (1977). Lat 39” 15’ to 39” 22'30", long 105” 45’ to 105” 52’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 31 by 33 inches.

GQ-1345. Geologic map of the Jefferson quadrangle, Park and Summit Counties, Colorado, by Fred Barker and D. G. Wyant. 1976. (1977). Lat 39” 22’30” to 39” 30', long 105” 45' to 105” 52’30”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 31 inches.

GQ-1403. Geologic map of the Canyon of Lodore south quadrangle, Moffat County, Colorado, by W. R. Hansen, 1977. Lat 40” 30’ to 40° 37'30", long 108” 52’30” to 109”. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 42 inches.

GEOPHYSICAL INVESTIGATIONS MAPS

GP-125. Airborne radioactivity survey of part of Moffat County, Cola., north of 40” 45', by R. W. Johnson. 1955. Scale 1:62,500. $1.25.

GP-126. Airborne radioactivity survey of part of Moffat County, Cola., south of 40” 45', by R. W. Johnson. 1955. Scale 1:62,500. $1.25.

GP-505. Natural gamma aeroradioactivity map of the Denver area, Colorado, by Peter Popenoe. 1965. Lat 39” 07’30” to 40” 35', long 104° to about 105” 15’. Scale 1:250,000. $1.25.

GP-557. Aeromagnetic map of the Denver area, Colorado, by A. J. Petty, J. L. Vargo, and F. C. Smith. 1966. Vicinity of lat 40°, long 104” 30’. Scale 1:250,000. $1.25.

GP-597. Aeromagnetic and gravity profiles of the United States along the 37th parallel—A contribution to the upper mantle project, by Isidore Zietz and J. R. Kirby. 1967. Lat 35” to 39°, long 70” to 125”. Scale 1:2,500,000. $1.25.

GP-638. Gravity map of the Trinidad quadrangle, Cola., by D. L. Peterson, Peter Popenoe, J. R. Gaca, and D. E. Karig. 1968. Lat 37” to 38°, long 104” to 106”. Scale 1:250,000. $1.25.

GP-836. Aeromagnetic map of Colorado, by Isidore Zietz and J. R. Kirby, Jr. 1972. Lat 37” to 41°, long 102” to 109”. Scale 1:500,000. $1.25.

GP-840. Aeromagnetic map of the Ridgway-Pagosa Springs area, southwestern Colorado. 1972 (1973). Lat 37” 15” to 38” 15", long 106°30' to 108°15'. Scale. 1:500,000. $1.25.

GP-880. Aeromagnetic map of Colorado, by Isidore Zietz and J. R. Kirby, Jr. 1972. Lat 37” to 41°, long 102” to 109”. Scale 1:000,000. $1.50.

GP-895. Bouguer gravity map of Colorado, compiled by J. C. Behrendt and L. Y. Bajwa. 1974. Lat 37” to 41”. long 102” to 109”. Scale 1:500,000. $1.25.

GP-896. Bouguer gravity and generalized elevated maps of Colorado, by J. C. Behrendt and L. Y. Bajwa. 1974 (1975). Lat 37’ to 41”. long 102” to 109”. Scale 1:1,000,000. 2 sheets. $2.75.

HYDROLOGIC INVESTIGATIONS ATLASES

HA-2. Areas of principal ground-water investigations in the Arkansas, White, and Red River basins, by S. W. Lohman and V. M. Burtis. 1953 (1954). Lat 31” to 39°, long 91’ to 106’. Scale 1:2,300,000. $1.

HYDROLOGIC INVESTIGATIONS ATLASES-Continued

HA-3. General availability of ground water and depth to water level in the Arkansas, White and Red River basins, by S. W. Lohman, V. M. Burtis, and others. 1953 (1954). Lat 31” to 39°, long 91” to 106”. Scale 1:2,500,000. (1975) $1.

HA-9. Ground-water resources of parts of Weld, Logan, and Morgan Counties, Colo., by L. J. Bjorklund, with a section on The Chemical quality of the ground water, by F. H. Rainwater. 1957 (1958). $1.50.

HA-41. Floods at Boulder, Colo. 1961 (1962). Scale 1:6,000. $1.75.

HA-61. Stream composition of the conterminous United States. bv E. H. Rainwater. 1962. 3 sheets. $6 per set.

HA-189. Calcium, sodium, sulfate, and chloride in stream water of the western conterminous United States to 1957, by J. H. Feth. 1965. 4 sheets. Scale 1:2,500,000. $5 per set.

HA-194. Generalized map showing annual runoff and productive aquifers in the conterminous United States, by C. L. McGuinness. 1964. Scale 1:5,000,000. $2.

HA-199. Preliminary map of the conterminous United States showing depth to and quality of shallowest ground water containing more than 1,000 parts per million dissolved solids, by J. H. Feth and others. 1965. Scale 1:3,168,000. 2 sheets. Accompanied by 31-page text. $1.75 per set.

HA-200. Chemical quality of public water supplies of the United States and Puerto Rico, 1962, shown as Statewide averages, mainly in graphic and tabular form, by C. N. Durfor and Edith Becker. 1964. $1.25.

HA-212. Annual runoff in the conterminous United States. bv M. W. Bushbv. 1966. Scale 1:7,500,000. $1.25.

HA-217. General availability of ground water and depth to water level in the Missouri River basin, by G. A. La Rocque, Jr. 1966. Lat 36” to 49°, long 90° to 114”. Scale 1:2,500,000. $1.75.

HA-235. Temperature of surface waters in the conterminous United States, by J. F. Blakey. 1966. Scale 1:5,000,000. 3 sheets. Accompanied by 8-page text. $1.75 per set.

HA-236. Ground water in Black Squirrel Creek valley, El Paso County, Colo., by H. E. McGovern and E. D. Jenkins. 1966. Vicinity of lat 38” 50′, long 104” 25’. $1.25.

HA-370. Geohydrology of the Piceance Creek structural basin between the White and Colorado Rivers. northwestern Colorado. bv D. L. Coffm. F. A. Welder, and R. K. Glanzman. 1971. Lat about 39” 15’ to 40” 15′, long about 108° to 108” 45’. 2 sheets. $2.50 per set.

HA-381. Hydrology of the San Luis Valley, south-central, Colorado, by P. A. Emery, A. J. Boettcher, R. J. Snipes, and H. J. McIntyre, Jr. 1971. Lat 37” to 38” 15′, long 105” 30’ to 106” 30’. 2 sheets. $2.50 per set.

HA-461. Hydrogeologic characteristics of the valley-fill aquifer in the Arkansas River valley, Bent County, Colo., by R. T. Hurr and J. E. Moore. 1972 (1973). Lat 38” to 38 10′, long 102” 45’ to 103” 22’30”. Scale 1:62,500. 2 sheets. $2.50 per set.

HA-477. Selected hydrologic data in the upper Colorado River basin, by Don Price and K. M. Waddell. 1973 (1974). Lat 36” to 43°, long 106” to 112”. Scale 1:2,500,000. 2 sheets. $3 per set.

HA-510. Reconnaissance investigation of ground water in the Rio Grande drainage basin—with special emphasis on saline ground-water resources, by T. E. Kelly. 1974. Lat 26” to 38” , long 98” to 108”. Scale 1:2,500,000. 4 sheets. $5.50 per set.

STATE HYDROLOGIC MAP

COLORADO. 1974. An overprint of the 1:500,000-scale State base map. Shows counties, location and names of all cities and towns and most of the smaller settlements, railroads, and township and range lines in black; water features in blue; hydrologic boundaries and codes in red; county codes in green. No contours. Sheet 41 by 58 inches. $1.25.

***INTERPRETING GEOLOGIC MAPS FOR ENGINEERING PURPOSES.** 1953 (1954). Six maps of the Hollidaysburg, Pa. quadrangle. Scale 1:62,500.

***LAND CLASSIFICATION MAPS OF THE CENTRAL GREAT PLAINS:**

*Sheet 4, Northeastern Colorado, by Depue Falck, E. R. Greenslet, and R. E. Morgan.

*Sheet 5, Southeastern Colorado, by Depue Falck, E. R. Greenslet, and R. E. Morgan.

*Western Colorado, by L. R. Brooks, J. F. Deeds, Depue Falck, E. R. Greenslet, G. M. Kerr, and J. Q. Peterson. 2 sheets.

MISCELLANEOUS FIELD STUDIES MAPS

MF-12. Geologic map of the Pando area, Eagle and Summit Counties, Colo., by Ogden Tweto. 1953 (1954). Lat 39” 25’ to 39” 30′, long 106” 12’30” to 106” 22’30”. Scale 1:14,400. $1.75.

*MF-13. Geology of the Northgate fluorspar district, Colorado, by T. A. Steven. 1954. Scale 1:24,000. 2 sheets. (See Bulletin 1082-F and Professional Paper 274-M.)

MF-16. Preliminary geologic map showing the distribution of uranium deposits and principal ore-bearing formations of the Colorado Plateau region, compiled by W. I. Finch. 1955. Scale 1:500,000. $1.25.

*MF-17. Preliminary geologic map of the Red Canyon quadrangle, Colorado, by D. J. McKay. 1954. Lat 38” 22’30”. to 38” 30′, long 108° 45’ to 108” 52’30”. Scale 1:24,000. See Map GQ-58.)

*MF-18. Preliminary geologic map of the Atkinson Creek quadrangle, Colorado, by E. J. McKay and D. A. Jobin. 1954. Lat 38” 22’30” to 38” 30′, long 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-57.)

*MF-19. Preliminary geologic map of the Gypsum Gap quadrangle, Colorado, by F. W. Cater, Jr. 1954 (1955). Lat 38” to 38” 07’30”., lonn 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-59.)

*MF-20. Preliminary geologic map of the Pine Mountain quadrangle, Colorado, by F. W. Cater, Jr. 1954. Lat 38” 37’30” to 38” 45′, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-60.)

*MF-21. Preliminary geologic map of the Hamm Canyon quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” to 38” 07′30″, long 108” 52’30”. Scale 1:24,000. (See Map GQ-69.)

*MF-22. Preliminary geologic map of the Paradox quadrangle, Colorado, by C. F. Withington. 1955. Lat 38” 15’ to 38” 22′30″, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-72.)

*MF-23. Preliminary geologic map of the Roc Creek quadrangle, Colorado, by E. M. Shoemaker. 1955. Lat 38” 22’30” to 38” 30′, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-83.)

*MF-24. Preliminary geologic map of the Uravan quadrangle, Colorado, by F. W. Cater, Jr., and E. J. McKay. 1955. Lat 38” 15’ to 38” 22’30”. lone 108° 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-78.)

*MF-25. Preliminary geologic map of the Anderson Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15′, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-77.)

*MF-26. Preliminary geologic map of the Egnar quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-68.)

*MF-27. Preliminary geologic map of the Joe Davis Hill quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 37” 52’30” to 38°, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-66.)

*MF-28. Preliminary geologic map of the Juanita Arch quadrangle, Colorado, by E. M. Shoemaker. 1955. Lat 38” 30’ to 38” 37’30”. long 108” 52’30” to 109”. Scale 1:24.000. (See Map GQ-81.)

*MF-29. Preliminary geologic map of the Horse Range Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1954 (1955). Lat 38” to 38” 07’30”, long 108” 52’30” to 109”. Scale 1:24,000. (See Map GQ-64.)

*MF-30. Preliminary geologic map of the Naturita NW quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 07’30” to 38” 15’. lone 108” 37’30” to 108” 45’. Scale 1:24,000. (See Map GQ-65.)

*MF-31. Preliminary geologic map of the Davis Mesa quadrangle, Colorado, by F. W. Cater, Jr., and E. J. McKay, 1955. Lat 38” 15’ to 38” 22′30″, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Map GQ-71.)

*MF-32. Preliminary geologic map of the Calamity Mesa quadrangle, Colorado, by F. W. Cater, Jr. 1955. Lat 38” 30’ to 38” 37’30”. long 108” 45’ to 108” 52’ 30”. Scale 1:24,000. (See Map GQ-61.)

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-34. Geologic map of the Tennessee Pass area, Eagle and Lake Counties, Colo., by Ogden Tweto. 1956. Scale 1:14,400.75¢.

*MF-37. Geologic and radiometric maps of the McKinley Mountain area, Wet Mountains, Colo.. by Q. D. Singewald and others, 1955. Scale 1:7,200. 4 sheets, (See Bulletin 1072-H and Map GQ-596.)

MF-54. Uranium and vanadium deposits of the Colorado Plateau that produced more than I.000 tons of ore through June 30, 1955. by R. T. Chew 3d. 1956. Scale 1:750,000. 75".

*MF-96. Preliminary geologic map of Placerville quadrangle, Colorado, by A. L. Bush, C. S. Bromfield, and C. T. Pierson. 1956. Lat 38" to 38" 07'30". long 108' to 108 07'30". Scale 1:24,000.(See Bulletin 1072-E.)

MF-120. Uranium deposits and principal ore-bearing formations of the central Cordilleran foreland region, by T. L. Finnell and I. S. Parrish. 1958. Scale 1:750,000. 2 sheets. $1.50 per set. (See Bulletin 1087-I.)

MF-122. Preliminary geologic map of sections of the western part of the Gateway district, Mesa County, Colo., and Grand County, Utah, by L. J. Eicher, D. C. Hedlund, and G. A. Miller. 1957. Lat 38" 36'15" to 38" 45'. long 109" to 109° 10'. Scale 1:24,000. 75'.

"MF-123. Preliminary geologic map of the Mount Peale 1 SE quadrangle, Montrose County. Colo., and San Juan County, Utah, by W. D. Carter and J. L. Gualtieri. 1957. Lat 38" 15' to 38' 22'30". long 109° to 109° 07'30". Scale 1:24,000.(See Professional Paper 508.)

*MF-130. Preliminary tectonic map of northern Colorado and northeastern Utah, showing the distribution of uranium deposits, compiled by F. W. Osterwald and B. G. Dean. 1958. Scale 1:500,000. 2 sheets. (See Bulletin 1087-I.)

*MF-132. Preliminary geologic map of the Sentinel Peak NW quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1957. Lat 37" 07'30" to 37" 15', long 108" 52'30" to 109°. Scale 1:24,000.(See Professional Paper 481.)

*MF-139. Preliminary geologic map of the Mount Peale 1 NE quadrangle, San Juan County, Utah, and Montrose County, Colo., by W. D. Carter, J. L. Gualtieri, and E. M. Shoemaker. 1958. Lat 38' 22'30" to 38" 30', long 109" to 109" 07'30". Scale 1:24,000.(See Professional Paper 508.)

MF-149. Preliminary geologic map of the Mount Peale 4 SE quadrangle, San Juan County, Utah, and San Miguel County, Colo., by G. W. Weir and W. P. Puffett. 1960 (1961). Lat 38" to 38" 07'30". long 109" to 109° 07'30". Scale 1:24,000.75¢.

MF-150. Preliminary geologic map and section of the Mount Peale 4 NE quadrangle, San Juan County. Utah, and Montrose and San Miguel Counties, Colo., by G. W. Weir. W. D. Carter. W. P. Puffett, and J. 0. Gualtieri. 1960. (1961). Lat 38" 07'30" to 38' 15'. long 109' to 109° 07'30". Scale 1:24,000.75¢.

MF-169. Exploration for uranium-vanadium deposits by the U.S. Geological Survey in the Club Mesa area, Uravan district, Montrose County, Colo., by R. L. Boardman, L. R. Litsey, and H. E. Bowers. 1958. Scale 1:7,200. $1.50.

MF-176. Preliminary geologic map of the Gray Head quadrangle, San Miguel County, Colo., by A. L. Bush, C. S. Bromfield, 0. T. Marsh, and R. B. Taylor. 1961. Lat 37" 52'30" to 38". long 107" 52'30" to 108". Scale 1:24,000. $1.50.

*MF-179. Preliminary map of bedrock geology of the Ralston Buttes quadrangle, Jefferson County, Colo., by D. M. Sheridan. C. H. Maxwell, A. L. Albee, and Richard Van Horn. 1958. Lat 39" 45' to 39" 52'30". long 105" 15' to 105" 22'30". Scale 1:24,000. (See Professional Paper 520.)

*MF-203. Preliminary geologic map of the Slick Rock district, San Miguel and Dolores Counties, Colo., by D. R. Shawe, G. C. Simmons, and W. B. Rogers. 1961. Lat 37" 45' to 38". lone 108" 37'30" to 109°. Scale 1:48,000. (See Bulletin 1107-B and Professional Pap& 576-A.)

*MF-216. Preliminary geologic map of the Moqui SW quadrangle. Montezuma County. Colo.. by F. N. Houser and E. B. Ekren. 1959. Lat 37" 15' to 37" 22'30", long 108" 52'30" to 109°. Scale 1:24,000.(See Professional Paper 481.)

*MF-217. Preliminary geologic map of the Cortez SW quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37" 15' to 37" 22'30", long 108" 37'30" to 108" 45'. Scale 1:24,000. (See Professional Paper 481.)

MISCELLANEOUS FIELD STUDIES MAPS-Continued

*MF-221. Preliminary geologic map of the Moqui SE quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37” 15’ to 37” 22′30″, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Professional Paper 481.)

‘MF-223. Preliminary geologic map of the Little Cone quadrangle, San Miguel County. Colo., by A. L. Bush, 0. T. Marsh, and R. B. Taylor. 1959. Lat 37” 52’30” to 38°, long 108” to 108” 07’30”. Scale 1:24,000. (See Bulletin 1082-G.)

“MF-224. Preliminary geologic map of the Sentinel Peak NE quadrangle, Montezuma County, Colo., by E. B. Ekren and F. N. Houser. 1959. Lat 37” 07’30” to 37” 15′, long 108” 45’ to 108” 52’30”. Scale 1:24,000. (See Professional Paper 481.)

*MF-241. Exploration for uranium-vanadium deposits by U.S. Geological Survey 1948-56 in western Disappointment Valley area, Slick Rock district, San Miguel County, Colo. (West half) (East half?, by W. B. Rogers and D. R. Shaw. 2 Scale 1:12,000. 3 sheets. (See Professional Paper 576-A.)

MF-271. Preliminary geologic map of the Hot Sulphur Springs SE quadrangle, Grand County, Colo., by G. A. Izett and D. L. Hoover. 1963. Lat 40” to 40° 07′30″, long 106” to 106” 07’30”. Scale 1:24,000. 75¢.

“MF-273. Preliminary geologic map of the Mount Wilson quadrangle, San Miguel and Dolores Counties, Colo., by C. S. Bromtield and A. R. Conroy. 1963 (1964). Lat 37” 45’ to 37” 52′30″, long 107” 52’30” to 108”. Scale 1:24,000. (See Bulletin 1227.)

MF-291. Preliminary geologic map of the Hot Sulphur Springs SW quadrangle, Grand County, Colo., by G. A. Izett and C. S. V. Barclay. 1964. Lat 40” to 40” 07′30″, long 106” 07’30” to 106” 15’. Scale 1:24,000. 75¢.

MF-308. Preliminary engineering geologic map of the Golden quadrangle, Jefferson County, Colo., by M. E. Gardner and S. S. Hart. 1971 (1972.) Lat 39” 45’ to 39” 52′30″, long 105” 07’30” to 105” 15’. 6 sheets. Scale 1:24,000. Accompanied by 21-page text, $4.50 per set.

MF-309. Structure contours and overburden on the top of the Mahogany zone, Green River Formation, in the northern part of the Piceance Creek basin, Rio Blanco County, Colo., by A. C. Austin. 1971 (1972). Lat 39” 45’ to about 40” 10′, long 108” to about 108” 35’. Scale 1:62.500. 75¢.

MF-346. Historic trail map of the La Junta 2” quadrangle, Colorado, compiled by G. R. Scott. 1972. Lat 37” to 38°, long 102” to 104”. Scale 1:250.000. 759.

MF-347. Preliminary geologic map of the Barcus Creek SE quadrangle, Rio Blanco County, Colo., by R. J. Hail, Jr. 1972. Lat 40” to 40” 07′30″, long 108” 15’ to 108” 22’30”. Scale 1:24,000. 2 sheets. $1.50 per set.

MF-348. Geologic map of the Arvada quadrangle, Adams, Denver, and Jefferson Counties, Colo., by R. M. Lindvall. 1972. Lat 39” 45’ to 39” 52′30″, long 105” to 105° 07’30”. Scale 1:24,000. 2 sheets. $1.50 per set.

MF-352. Reconnaissance geologic map of the Beulah NE quadrangle, Pueblo County, Colo., by G. R. Scott. 1972. Lat 38” 07’30” to 38” 15′, long 104” 45’ to 104” 52’30”. Scale 1:24,000. 75¢.

MF-353. Reconnaissance geologic map of the Hobson quadrangle, Pueblo and Fremont Counties, Colo., by G. R. Scott. 1972. Lat 38” 15’ to 38” 22′30″, long 104” 52’30” to 105”. Scale 1:24,000. 75¢.

MF-354. Reconnaissance geologic map of the Swallows quadrangle, Pueblo County, Colo., by G. R. Scott. 1972. Lat 38” 15’ to 38” 22′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. 75¢.

MF-482. Reconnaissance geologic map of Colorado Springs and vicinity, Colorado, by G. R. Scott and R. A. Wobus. 1973. Lat 38” 37’30” to 39°, long 104” 37’30” to 105”. Scale 1:62,500. 2 sheets. $1.50 per set.

MF-513. Map showing mined areas of the Boulder-Weld coal field, Colorado, by R. B. Colton and R. L. Lowrie. 1973. Lat 39” 55’ to 40” 07′30″, long 104” 52’30” to 105° 15’. Scale 1:24,000. 75¢.

MF-547. Reconnaissance geologic map of the Owl Canyon quadrangle, Pueblo County, Colo., by G. R. Scott. 1973 (1974). Lat 38” 07’30” to 38” 15′, long 104” 52’30” to 105”. Scale 1:24,000. 75¢.

MF-548. Reconnaissance geologic map of the Wetmore quadrangle, Custer and Pueblo Counties, Colo., by R. B. Taylor and G. R. Scott. 1973 (1974). Lat 38” 07’30” to 38” 15′, long 105” to 105° 07’30”. Scale 1:24,000. 75¢.

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-551. Reconnaissance geologic map of the Beulah quadrangle, Pueblo County, Colo., by G. R. Scott and R. B. Taylor. 1973 (1974). Lat 38" to 38" 07'30", long 104" 52'30" to 105". Scale 1:24,000. 75¢.

MF-555. Reconnaissance geologic map of the Fair-play West, Mount Sherman, South Peak, and Jones Hill 7%minute quadrangles, Park, Lake, and Chaffee Counties, Colo., by Ogden Tweto. 1974. Lat 39" to 39" 15', long 106" to 106° 15'. Scale 1:62,500. 75¢.

MF-556. Geologic map of the Mount Lincoln 15-minute quadrangle, Eagle, Lake, Park, and Summit Counties. Colo.. by Ogden Tweto. 1974. Lat 39" 15' to 39" 30'. long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-562. Reconnaissance geologic map of the Rockvale quadrangle, Custer and Fremont Counties, Colo.. by G. R. Scott and R. B. Taylor. 1974. Lat 38" 15' to 38" 22'30". lone 105" 07'30" to 105" 15'. Scale 1:24,000. 75¢.

MF-570. Preliminary geologic map of the Segar Mountain quadrangle, Rio Blanco County, Colo., by R. B. O'Sullivan. 1974. Lat 39" 52'30" to 40°, long 108" to 108" 07'30". Scale 1:24,000. 75¢.

MF-597. Reconnaissance geologic map of the Conifer quadrangle, Jefferson County, Colo., by Bruce Bryant. 1974. Lat 39" 30' to 39" 37'30", long 105" 15' to 105" 22'30". Scale 1:24,000. 75'.

MF-598. Reconnaissance geologic map of the Pine quadrangle, Jefferson County, Colo., by Bruce Bryant. 1974. Lat 39" 22'30" to 39" 30', long 105" 15' to 105" 22'30". Scale 1:24,000. 75¢.

MF-619. Preliminary geologic map and section of the Barcus Creek quadrangle, Rio Blanco County, Colo., by W. J. Hall, Jr. 1974. Lat 40° to 40° 07'30", long 108" 22'30" to 108" 30'. Scale 1:24,000. 75¢.

MF-628. Reconnaissance geologic map of the Electric Peak quadrangle, Custer and Saguache Counties, Colo., by G. R. Scott and R. B. Taylor. 1974. Lat 38" to 38" 15', long 105" 30' to 105" 45'. Scale 1:62,500. 75¢. (Reprinted 1977.)

MF-631. Geologic map and engineering data for the Highlands Ranch quadrangle, Arapahoe and Douglas Counties. Colo., by J. 0. Maberry and R. M. Lindvall. 1974 (1975). Lat 39" 30' to 39° 37'30", long 104° 52'30" to 105°. Scale 1:24,000. 3 sheets. $2.25 per set.

MF-651. Preliminary geologic map of the Buckskin Point quadrangle, Rio Blanco County, Colo., by G. N. Pipiringos and R. C. Johnson. 1975. Lat 40" to 40" 07'30", long 108 to 108" 07'30". Scale 1:24,000. Structure-contour interval 100 feet. 75¢.

MF-656. Geologic map of the Lafayette quadrangle, Adams. Boulder, and Jefferson Counties, Colo., by M. N. Machette. 1975. Lat 39° 52'30" to 40°, long 105" to 105" 07'30". Scale 1:24,000. 75¢.

MF-657. Reconnaissance geologic map of the Buena Vista quadrangle, Chaffee and Park Counties, Colo., by G. R. Scott. 1975. Lat 38" 45' to 39°, long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-658. Geologic map of the Poncha Springs quadrangle, Chaffee County, Colo., by G. R. Scott, R. E. Van Alstine, and W. N. Sharp. 1975. Lat 38" 30' to 38" 45', long 106" to 106" 15'. Scale 1:62,500. 75¢.

MF-666. Preliminary geologic map of the Craig 1" by 2" quadrangle, northwestern Colorado, compiled by Ogden Tweto. 1975. Lat 40" to 41°, long 106' to 108". Scale 1:250,000. 75¢.

MF-682. Reconnaissance geologic map of the Chama Peak quadrangle, Conejos and Archuleta Counties, Colo., by P. W. Lipman and W. J. Hail, Jr. 1975. Lat 37" to 37" 15', long 106" 45'. Scale 1:48,000. 75¢.

MF-688. Preliminary geologic map, oil shale yield histograms and stratigraphic sections, Long Point quadrangle, Garfield County, Colo., by R. C. Johnson. 1975. Lat 39 22'30" to 39" 30", long 108" 15' to 108" 22'30". Scale 1:24,000. 2 sheets. $1.50.

MF-689. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Ralston Buttes quadrangle and adjoining areas to the east and west in Jefferson County, Colo., by K. L. Pierce and P. W. Schmidt. 1975. Lat 39 45' to 39" 52'30", long about 105" 14' to 105" 24'. Scale 1:24,000. 75¢.

MF-691. Preliminary geologic map of the Cutoff Gulch quadrangle, Rio Blanco and Garfield Counties, Colo., by W. J. Hail, Jr. 1975. Lat 39" 37'30" to 39" 45', long 108" 07'30" to 108° 15'. Scale 1:24,000. 2 sheets. $1.50.

MF-695. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Eldorado Springs quadrangle, Boulder and Jefferson Counties, Colo., by K. L. Pierce and P. W. Schmidt. 1975. Lat 39” 52’30” to 40°, long 105” 15’ to about 105” 22’30”. Scale 1:24,000. 75¢.

MF-696. Preliminary map of landslide deposits, Vernal 1” by 2” quadrangle, Colorado and Utah, by P. E. Carrara, R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 40” to 41°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-697. Preliminary map of landslide deposits, Grand Junction 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton, J. A. Holligan, L. W. Anderson, and K. C. Shaver. 1975. Lat 37” to 38°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-698. Preliminary map of landslide deposits, Moab 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton, J. A. Holligan, L. W. Anderson, and K. C. Shaver. 1975. Lat 38” to 39°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-699. Preliminary map of landslide deposits, Cortez 1” by 2” quadrangle, Colorado and Utah, by R. B. Colton L. W. Anderson, J. A. Holligan, P. E. Patterson, and K. C. Shaver. 1975. Lat 37” to 38°, long 108” to 110”. Scale 1:250,000. 75¢.

MF-700. Preliminary map of landslide deposits, Craig 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, P. E. Patterson, and L. W. Anderson. 1975. Lat 40” to 41”. long 106° to 108”. Scale 1:250,000. 75¢.

MF-701. Preliminary map of landslide deposits, Leadville 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, L. W. Anderson, and P. E. Patterson. 1975. Lat 39” to 40°, long 106” to 108°. Scale 1:250,000. 75¢.

MF-702. Preliminary map of landslide deposits, Montrose 1” by 2” quadrangle, Colorado, by R. B. Colton, P. E. Patterson, J. A. Holligan, and L. W. Anderson. 1975. Lat 38” to 39°, long 106” to 108”. Scale 1:250,000. 75¢.

MF-703. Preliminary map of landslide deposits, Durango 1° by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 37” to 38°, long 106” to 108”. Scale 1:250,000. 759.

MF-704. Preliminary map of landslide deposits, Greeley 1° by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 40” to 41°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-705. Preliminary map of the landslide deposits, Denver 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 39” to 40” long 104 to 106”. Scale 1:250,000. 75¢.

MF-706. Preliminary map of landslide deposits, Pueblo 1° by 2” quadrangle, Colorado, by R. B. Colton, G. R. Scott, J. A. Holligan, and L. W. Anderson. 1975. Lat 38” to 39°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-707. Preliminary map of landslide deposits, Trinidad 1” by 2” quadrangle, Colorado, by R. B. Colton, J. A. Holligan, and L. W. Anderson. 1975. Lat 37” to 38°, long 104” to 106”. Scale 1:250,000. 75¢.

MF-708. Preliminary map of landslide deposits, La Junta 1” by 2” quadrangle, Colorado and Kansas, by R. B. Colton, L. W. Anderson, and J. A. Holligan. 1975. Lat 37” to 38°, long 102” to 104”. Scale 1:250,000. 75¢.

MF-713. Geologic map of the Spring Hill Creek quadrangle, Saguache County, Colo., by J. C. Olson, T. A. Steven, and D. C. Hedlund. 1975. Lat 38” 15’ to 38” 22′30″, long 106 52′30″ to 107”. Scale 1:24,000. 75¢.

MF-733. Geologic map of the Sawtooth Mountain quadrangle, Saguache County, Colo., by J. C. Olson and T. A. Steven. 1976. Lat 38” 15’ to 38” 22′30″, long 106” 45’ to 106” 52’30”. Scale 1:24,000. 75¢.

MF-736. Preliminary geologic map and correlation diagram of the White River City quadrangle, Rio Blanco County, Colo., by G. N. Pipiringos and R. C. Johnson. 1976. Lat 40” to 40° 07′30″, long 108” 07’36” to 108” 15’. Scale 124,000. $1.25.

MF-740. Reconnissance map showing relative amounts of soil and bedrock in the mountainous part of the Morrison-Evergreen quadrangles and adjoining areas to the west in Jefferson County, Colorado, by P. W. Schmidt. 1976. Lat 39” 37’30” to 39” 45′, long 105° 10′ to about 105” 22’30”. 75¢.

MF-741. Reconnaissance map showing relative amounts of soil and bedrock in the mountainous part of the Indian Hills auadranele. in Jefferson County. Colorado. by P. W. Schmidt. 1976. Lat 39" 30' to 39° 37'30", long 105° 07'30" to 105° 15'. Scale 1:24,000. $1.25.

MF-746. Structure contours and overburden on the top of the Mahogany zone, Green River Formation, in the southern part of Piceance Creek basin, Rio Blanco and Garfield Counties, Colo., by M. C. Mullens. 1976. Lat about 39" 20' to 39" 45', long about 108" to about 108" 40'. Scale 1:63,360. 75¢.

MF-748. Geologic map of the Razor Creek Dome quadrangle, Saguache County, Colo., by J. C. Olson and T. A. Steven. 1976. Lat 38" 15' to 38" 22'30", long 106" 37'30" to 106" 45'. Scale 1:24,000. 75¢.

MF-753. Preliminary geologic map of Wolf Ridge quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 22'30" to 108" 30'. Scale 1:24,000. 75'.

MF-754. Preliminary geologic map of Square S Ranch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 15' to 108" 22'30". Scale 1:24,000. 75¢.

MF-755. Preliminary geologic map of Greasewood Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 52'30" to 40°, long 108" 07'30" to 108" 15'. Scale 1:24,000. 75¢.

MF-756. Preliminary geologic map of Jessup Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 45' to 39" 52'30", long 108" 07'30" to 108" 15'. Scale 1:24,000. 75¢.

MF-757. Preliminary geologic map of Rock School quadrangle, Rio Blanco County, Colo., by D. C. Duncan. Lat 39" 45' to 39" 52'30", long 108" 15' to 108" 22'30". Scale 1:24,000. 75¢.

MF-758. Preliminary geologic map of Yankee Gulch quadrangle, Rio Blanco County, Colo., by D. C. Duncan. 1976. Lat 39" 45' to 39" 52'30", long 108" 22'30" to 108" 30'. Scale 1:24,000. 75'.

MF-759. Reconnaissance geologic map of the Glentivar quadrangle, Park County, Colo., by R. A. Wobus. 1976. Lat 39" to 39" 07'30". lone 105" 30' to 105" 37'30". Scale 1:24,000. 75¢.

MF-760. Preliminary geologic map of the Leadville 1" x 2" quadrangle, northwestern Colorado, by Ogden Tweto, R. H. Moench, and J. C. Reed, Jr. 1976. Lat 39" to 40°, long 106" to 108". Scale 1:250,000. 75¢.

MF-761. Preliminary geologic map of the Montrose 1" x 20" quadrangle, southwestern Colorado, by Ogden Tweto, T. A. Steven, W. J. Hail, Jr., and R. H. Moench. 1976. Lat 38" to 39". lone 106" to 108". Scale 1:250,000. 75¢. (Reprinted 1977.)

MF-770. Reconnaissance map showing relative amounts of soil and bedrock in the Conifer quadrangle and adjoining areas to the west in Jefferson County, Colorado, by P. W. Schmidt, 1976. Lat 39" 30' to 39" 37'30", long 105" 15' to 105" 22'30". Scale 1:24,000. 75'

MF-771. Preliminary landslide overview map of the conterminous United States, by D. H. Radbruch-Hall, R. B. Colton, W. E. Davis, B. A. Skipp, Ivo Lucchitta, and D. J. Vamers. 1976. Lat 25" to 50°, long 65" to 125" Scale 1:7,500,000. 75¢.

MF-775. Geologic map of the Pueblo 1" by 2" quadrangle, south-central Colorado, by G. R. Scott, R. B. Taylor, R. C. Epis, and R. A. Wobus. 1976. Two sheets. Lat 38" to 39°, long 104" to 106". Scale 1:187,500 (1 inch = about 2.9 miles). Sheet 1, 30 by 40 inches; sheet 2, 30 by 36 inches $1.50. (Reprinted 1977.1

MF-778. Reconnaissance geologic map of the Picacho Mountains, Arizona, by Warren Yeend. 1976. Lat about 32" 40' to 33°, long 111" 15' to 11" 30'. Scale 1:62,500 (1 inch = about 1 mile). Sheet 25 by 31 inches. 75¢.

MF-786. Preliminary overview map of volcanic hazards in the 48 conterminous United States, by D. R. Mullineaux. 1976 (19771. Lat about 25" to about 50°, long about 65' to about 125". Scale 1:7,500,000 (1 inch = about 118 miles). Sheet 29 by 36 inches. 75¢. (Reprinted 1977.)

MF-788. Preliminary geologic map of Colorado, compiled by Ogden Tweto. 1976 (1977). Two sheets. Lat 37" to 41°, long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 1, 42 by 52 inches; sheet 2, 42 by 34 inches. $1.50 per set.

MISCELLANEOUS FIELD STUDIES MAPS-Continued

MF-797. Isopach map and cross section of the Mahogany zone of the Green River Formation derived principally from geophysical well logs, eastern Uinta Basin, Utah and Colorado, by W. B. Cashion and G. H. Dixon. 1976. Lat about 39" 52' 30" to about 40" 30', long 108" to 110". Scale 1:250,000 (1 inch = 4 miles). Sheet 26% by 31 inches. 75".

MF-803. Reconnaissance map showing relative amounts of soil and bedrock in the Platte Canyon quadrangle, Jefferson County, Colorado, by P. W. Schmidt. 1976 (1977). Lat 39" 22'30" to 39" 30', long 105" 07'30" to 105" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 32 by 40 inches. 75¢.

MF-804. Reconnaissance map showing relative amounts of soil and bedrock in the Pine quadrangle and adjoining areas to the west in Jefferson County, COLORADO, by P. W. Schmidt. 1976 (1977). Lat 39" 22'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by inches. 75¢.

MF-805. Reconnaissance geologic map of the Cripple Creek-Pikes Peak area, Teller, Fremont, and El Paso Counties, Colorado, by R. A. Wobus, R. C. Epis, and G. R. Scott. 1976. Lat 38" 37'30" to 38" 52'30", long 105" to 105" 15'. Scale 1:48,000 (1 inch = 4,000 feet). Sheet 27 by 40 inches. 75¢. (Reprinted 1977.)

MF-810. Geologic map and details of the beryllium and molybdenum occurrences, Mount Antero, Chaffee County, Colorado, by W. N. Sharp. 1976 (1977). Lat about 38" 35' to 42" 30', long about 106" 10' to 106" 17'30". Scale 1:24,000 (1 inch = 2,000 feet). Two sheets: sheet 1, 32 by 42 inches; sheet 2, 24 by 44 inches. $1.50 per set.

MF-812. Seismicity map of the conterminous United States and adjacent areas, 1965-1974, by C. W. Stover. 1977. Lat about 25" to about 50°, long about 65" to about 125". Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 30 by 46 inches. 75¢.

MF-816. Reconnaissance geologic map of the Bailey quadrangle, Jefferson and Park Counties, Colorado, by Bruce Bryant. 1976 (1977). Lat 39" 22'30" to 39" 30', long 105" 22'30" to 105" 30'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 36 inches. 75¢.

MF-819. Map showing potential snow avalanche areas in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke. 1976. Lat 37" 52'30" to 38°, long 107" 45' to 107" 52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. 75¢.

MF-824. Geologic map of the Weaver Ridge quadrangle, Uintah County, UTAH, and Rio Blanco County, COLORADO, by W. B. Cashion. 1977. Lat 39" 52'30" to 40°, long 109" to 109" 07'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 26 by 33 inches. 75¢.

MF-829. Preliminary geologic map and cross section of the Saddle quadrangle, Garfield County, COLORADO, by R. C. Johnson. 1977. Lat 39" 22' 30" to 39" 30', long 108" 22'30" to 108" 30'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 42 by 46 inches. 75¢.

MF-830. Preliminary geologic map of the Bull Fork quadrangle, Garfield and Rio Blanco Counties, COLORADO, by W. J. Hail, Jr. 1977. Lat 39" 37'30" to 39" 45', long 108 15' to 108" 22'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 44 inches. 75'.

MF-831. Preliminary geologic map of the Fort Logan quadrangle, Jefferson, Denver, and Arapahoe Counties, COLORADO, by R. M. Lindvall. 1976 (1977). Lat 39" 37'30" to 39" 45', long 105" to 105" 07'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 31 by 44 inches. 75¢.

MF-836. Preliminary geologic map of the Indian Valley quadrangle, Rio Blanco and Moffat Counties, COLORADO, by G. N. Pipiringos and G. C. Rosenlund. 1977. Lat 40 07'30" to 40" 15', long 108" 07'30" to 108" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 36 inches. 75¢.

MF-837. Preliminary geologic map of the White Rock quadrangle, Rio Blanco and Moffat Counties, Colorado. by G. N. Pipiringos and G. C. Rosenlund. 1977. Lat 40° 07'30" to 40° 15', long 108" to 108" 07'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 34 by 42 inches. 75¢.

MF-842. Reconnaissance geologic map of the Woodland Park quadrangle, Teller County, Colorado, by R. A. Wobus and G. R. Scott. 1977. Lat 38" 52' 30" to 39°, long 105" to 105" 07'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 31 inches. 75¢.

MF-861. Map and list of reported occurrences of platinum-group metals in the conterminous United States, by W. N. Blair, N. J Page and M. G. Johnson. 1977. 2 sheets. Scale 1:5.000,000 (1 inch = about 80 miles). Sheet 1, 35 by 41 inches; sheet 2, 29% by 31 inches. $1.50 per set.

MF-871. Photo interpretive map showing areas underlain by landslide deposits and areas susceptible to landsliding in the Louisville quadrangle, Boulder and Jefferson Counties, Colorado, by R. B. Colton and J. A. Holligan. 1977. Lat 39” 52’30” to 40°, long 105” 07’30” to 105” 15’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. 75¢

MF-882: Preliminary geologic map of the Erie quadrangle, Boulder, Weld, and Adams Counties. Colorado, by R. B. Colton and L. W. Anderson. 1957. Lat 40” to 40” 07′30″, long 105” to 105” 07′30″. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 28 by 35 inches. 75¢.

MF-892. Reconnaissance geologic map of the Canon City quadrangle, Fremont County, Colorado, by G. R. Scott, 1977. Lat 38” 22’30” to 38” long 105” 07’30” to 105” 15’. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 30 by 37 inches. 75¢.

MINERAL INVESTIGATIONS RESOURCE MAPS

The following maps cover the resources indicated for the United States exclusive of Alaska and Hawaii. All are printed at a scale of 1:3,168,000 and are sold at $1.25 each, unless otherwise indicated.

MR-2. Uranium deposits, compiled by R. W. Schnable. 1955. Scale 1:5,000,000. $1.75.
MR-3. Potash occurrences, by M. F. Byrd. 1955. Scale 1:5,000,000. $1.75.
MR-13. Copper, by A. R. Kinkle, Jr., and N. P. Peterson. 1962.
MR-14. Borates, by W. C. Smith. 1962.
MR-15. Lead, by E. T. McKnight, W. L. Newman, and A. V. Heyl, Jr. 1962.
MR-16. Vanadium, by R. P. Fischer. 1962.
MR-17. Asbestos, by A. H. Chidester and A. F. Shride. 1962.
MR-18. Pyrophyllite, and kyanite and related minerals, by G. H. Espenshade. 1962.
MR-19. Zinc, by E. T. McKnight, W. L. Newman, and A. V. Heyl, Jr. 1962.
MR-20. Antimony, by D. E. White. 1962.
MR-21. Epigenetic uranium deposits, by A. P. Butler, Jr., W. I. Finch, and W. S. Twenhofel. 1962.
MR-22. Bismuth, by J. R. Cooper. 1962.
MR-23. Manganese, by M. D. Crittenden and Louis Pavlides. 1962.
*MR-24. Gold, by A. H. Koschmann and M. H. Bergendahl. 1962.
MR-25. Tungsten, by D. M. Lenunon and 0. L. Tweto. 1962.
MR-26. Chromite, by T. P. Thayer and M. H. Miller. 1962.
MR-27. Magnesite and brusite, by Benjamin Gildersleeve. 1962.
MR-28. Thorium and rare earths, by J. C. Olson and J. W. Adams. 1962.
MR-29. Titanium, by C. L. Rogers and M. C. Jaster. 1962.
MR-30. Mercury, by E. H. Bailey. 1962.
MR-31. Talc and soapstone, by A. H. Chidester and H. W. Worthington. 1962.
MR-33. Gypsum and anbydrite, by C. F. Withington. 1962.
*MR-34. Silver, by E. T. McKnight, W. L. Newman, Harry Klemic, and A. V. Heyl, Jr. 1962.
MR-35. Beryllium, by W. R. Griffitts, D. M. Larrabee, and J. J. Norton. 1962.
MR-36. Niobium and tantalum, by R. L. Parker, 1963.
MR-37. High-alumina kaolinitic clay, by Helen Mark. 1963.
MR-43. Barite, by D. A. Brobst. 1965.
MR-44. Tin, by P. L. Killeen and W. L. Newman. 1965.
MR-51. Iron, by M. S. Carr, P. W. Guild, and W. B. Wright. 1967. Accompanied by 20-page text.
MR-55. Molybdenum, by R. U. King. 1970. Accompanied by 21-page text.
MR-57. Reported occurrences of selected minerals in Colorado. 1971. Scale 1:500,000.
MR-58. Map showing localities and amounts of metallic mineral production in Colorado, by W. R. Marsh and R. W. Queen. 1974. Lat 37” to 41°, long 102” to 109”. Scale 1:500,000.
MR-60. Fluorite, compiled by R. G. Worl, R. E. Van Alstine, and A. V. Heyl, 1974. Accompanied by 13-page text.
MR-70. Map showing fluorspar deposits in Colorado, compiled by B. T. Brady. 1975 (1976). Lat 37” to 41°, long 102” to 109”. Scale 1500,000. Accompanied by 20-page text.

MINERAL INVESTIGATIONS (STRATEGIC) MAPS

*3-173. Geologic map of the Gateway area, Mesa County, Colo., and adjoining part of Grand County, Utah, by W. L. Stokes, R. T. Russell, R. P. Fischer, and A. P. Butler, Jr. 1945. Scale 1:63,360.

*3-212. Iron-ore deposits of the Western United States, by C. E. Dutton and M. S. Carr 1947 Scale 1:5,000,000. (See Bulletin 1082-C and Map MR-51.)

*3-226. Vanadium region of southwestern Colorado and southeastern Utah, by R. P. Fischer. 1947. Scale 1:187,500. (See Bulletin 936-P.)

MISCELLANEOUS INVESTIGATIONS SERIES

I-90. Photogeologic map of the Aneth-1 quadrangle, San Juan County, Utah, and Montezuma County, Colo., by R. J. Hackman. 1965. Lat 37” 22’30” to 37” 30′, long 109° to 109” 07’30”. Scale 1:24,000. $1.25.

I-97. Photogeologic map of the Aneth-8 quadrangle, San Juan County, Utah, and Montezuma Countv. Colo.. bv R. J. Hackman. 1955. Lat 37” 15’ to 37” 22′30″, long 109° to 109” 07’30”. Scale 1~24,000. $1.25.

I-157. Photogeologic map of the Mount Peale-S quadrangle, San Juan County, Utah, and Montrose and San Miguel Counties, Colo., by R. J. Hackman. 1956. Lat 38” 07’30” to 38” 15′, long 109° to 109” 07’30”. Scale 1:24,000. $1.25.

I-165. Photogeologic map of the Mount Peale-l quadrangle, San Juan County, Utah, and Montrose County, Colo., by R. J. Hackman. 1956. Lat 38” 22’30” to 38” 30′, long 109” to 109” 07’30”. Scale 1:24,000. $1.25.

I-174. Photogeologic map of the Mount Peale-8 quadrangle, San Juan County, Utah, and Montrose County, Colo., by R. J. Hackman. 1956. Lat 38” 15’ to 38” 22′30″, long 109” to 109” 07’30”. Scale 1:24,000. $1.25.

I-175. Paleotectonic maps of the Jurassic System, by E. D. McKee, S.S. Oriel, V. E. Swanson, J. E. MacLachlan, J. C. MacLachlan, K. B. Ketner, J. W. Goldsmith, R. Y. Bell, and D. J. Jameson, with a separate section on Paleogeography, by R. W. Imlay. 1956. Scales 1:2,500,000 and 1:5,000,000. $15.

I-176. Photogeologic map of the Mount Peale-16 quadrangle, San Juan County, Utah, and San Miguel County, Colo., by R. J. Hackman. 1956. Lat 38” to 38” 07′30″, long 109 to 109” 07’30”. Scale 1:24,000. $1.25.

I-274. Photogeologic map of the Escalante Forks quadrangle, Mesa, Montrose, and Delta Counties, Colo., by R. J. Hackman. 1958. Lat 38” 30’ to 38” 45′, long 108” 15’ to 108” 30’. Scale 1:62,500. $1.25.

I-277. Photogeologic map of the Iris SE and Doyleville SW quadrangles, Saguache County, Colo., by Kathleen McQueen. 1958. Lat 38” 15’ to 38” 22′30″, long 106” 37’30” to 106” 52’30”. Scale 1:31,680. $1.25.

I-278. Photogeologic map of the Coach Creek SE quadrangle, Grand County, Utah, and Mesa County, Colo., by R. J. Hackman. 1959. Lat 38” 45’ to 38” 52′30″, long 109” to 109” 07’30”. Scale 1:24,000. $1.25.

I-279. Photogeologic map of the Coach Creek NE quadrangle, Grand County, Utah, and Mesa County, Colo., by R. J. Hackman. 1959. Lat 38” 52’30” to 39°, long 109” to 109” 07’30”. Scale 1:24,000. $1.25.

I-281. Photogeologic map of the Yellow Jacket quadrangle, Montezuma and Dolores Counties, Colo., by R. J. Hackman. 1959. Lat 37” 30’ to 37” 45′, long 108” 30’ to 108” 45’. Scale 1:62,500. $1.25.

I-282. Photogeologic map of the Delta quadrangle, Montrose and Delta Counties, Colo., by C. H. Marshall. 1959. Lat 38” 30’ to 38” 45′, long 108° to 108” 15’. Scale 1:62,500. $1.25.

I-283. Photogeologic map of the Norwood-l quadrangle, Montrose and Ouray Counties, Colo., by C. H. Marshall. 1959. Lat 38” 15’ to 38” 30′, long 108” to 108° 15’. Scale 1:62,500. $1.25.

I-299. Epigenetic uranium deposits in the United States, by W. I. Finch, I. S. Parrish, and G. W. Walker. 1959. Scale 1:5,000,000. 3 sheets. $4.25 per set.

I-300. Paleotectonic maps of the Triassic System, by E. D. McKee, S. S. Oriel, K. B. Ketner, M. E. MacLachlan, J. W. Goldsmith, J. C. MacLachlan, and M. R. Mudge. 1959. Scale 1:5,000,000. $15.

I-309. Geologic map of the igneous and metamorphic rocks of Colorado showing location of uranium deposits, compiled by E. A. Merewether. 1960. Lat 37” to 41°, long 102” to 109”. Scale 1:500,000. $1.50.

I-322. Geologic map of the Willow Creek Butte quadrangle, Utah-Colorado, by W. R. Hansen. 1961. Lat 40° 52'30" to 41°, long 109° to 109° 07'30". Scale 1:24,000. $1.50.

I-332. Geologic map of a part of southwestern Wyoming and adjacent States, by W. H. Bradley. 1961. Scale 1:250,000. $1.25.

I-333. Preliminary geologic map of the Indian Hills quadrangle, Jefferson County, Colo., by G. R. Scott. 1961. Lat 39" 30' to 39° 37'30". long 105' 07'30" to 105°15'. Scale 1:24,000. $1.25.

I-360. Geology, structure. and uranium deposits of the Moab quadrangle, Colorado and Utah, compiled by P. L. Williams, 1964. Lat 38" to 39°, long 108" to 110°. Scale 1:250,000. 2 sheets. $3.25 per set. (Reprinted 1977.)

I-383. Preliminary geologic map of the Eldorado Springs quadrangle, Boulder and Jefferson Counties, Colo., by J. D. Wells. 1963. Lat 39" 52'30" to 40°, long 105" 15' to 105" 22'30". Scale 1:24,000. $1.25.

I-387. Fluoride content of ground water in the conterminous United States, by Michael Fleischer. 1962. Scale 1:5,000,000. $1.25.

I-404. Geologic map of the Grand Junction area, Colorado, by S. W. Lohman. 1975, Lat about 38" 48' to about 39" 12', long 108" 25' to 108" 47'. Scale 1:31,680. $1.75.

I-408. Geology of the Northwest and Northeast Pueblo quadrangles, Colorado, by G. R. Scott. 1964. Lat 38" 15' to 38" 22'30", long 104" 30' to 104" 45'. Scale 1:24,000. $1.25.

I-428. Geology of the sedimentary rocks of the Morrison quadrangle, Colorado, by J. H. Smith. 1964. Lat 39" 37'30" to 39" 45'. long 105" 07'30" to 105" 15'. Scale 1:24,000. Accompanied by 3-page text. $1.25.

I-439. Geologic and biostratigraphic map of the Pierre Shale between Jarre Creek and Loveland, Colo., by G. R. Scott and W. A. Cobban. 1965. Lat 39" 52'30" to 40" 22'30", long 104" 50' to 105' 17'30". Scale 1:48,000. Accompanied by I-page text. $1.75.

I-443. Preliminary geologic map of the Berthoud Pass quadrangle, Clear Creek and Grand Counties, Colo., by P. K. Theobald. 1965. Lat 30" 45' to 39° 52'30", long 105" 45' to 105" 52'30". Scale 1:24,000. $1.25.

I-448. Geologic and crustal cross section of the United States along the 37th parallel-A contribution to the upper mantle project, by Warren Hamilton and L. C. Pakiser. 1965. Scale 1:2,500,000. $1.50.

I-450 Paleotectonic maps of the Permian System, by E. D. McKee, S. S. Oriel, and others. 1967. $38.

I-496 Distribution of selected accessory minerals in the Caribou stock, Boulder County, Colo., by G. J. Neuerburg. 1967. Vicinity of lat 40°, long 105" 35'. Scale 1:12,000. $1.25.

I-558 Geologic map of the Trinidad quadrangle, south-central Colorado, by R. B. Johnson. 1969. Lat 37" to 38°, long 104" to 106". Scale 1:250,000. $1.50.

I-560 Geologic and structure contour map of the La Junta quadrangle, Colorado and Kansas, by G. R. Scott. 1968 (1969) Lat 37" to 38°, long 102" to 104". Scale 1:250,000. $1.75.

I-563 Geologic map and sections of the southwest quarter of the Dillon quadrangle, Eagle and Summit Counties, Colo., by M. H. Bergendahl. 1969. Lat 39" 30' to 39" 37'30", long 106" 07'30" to 106° 15'. Scale 1:24,000. $1.50.

I-584 Geologic Map of the Black Canyon of the Gunnison River and vicinity, western Colorado, by W. R. Hansen. 1971. Sheet 1, lat 38" 30' to 38" 37'30". long 107" 30' to 107" 52'30"; sheet 2, lat 38" 22'30" to 38" 30', long 107" 15' to 107" 37'30". Scale 1:31,680. 2 sheets. $3.50 per set.

I-597. Geologic map of the Southwest and Southeast Pueblo quadrangles, Colorado, by G. R. Scott. 1969 (1970). Lat 38" 07'30" to 38" 15'. long 104" 30' to 104" 45'. Scale 1:24,000. $1.75.

I-608. Maps showing distribution of selected accessory minerals in the Montezuma stock, Summit County, Colo., by G. J. Neuerburg. 1971. Lat about 39" 35' to 39" 37'30", long about 105" 50' to 105° 55'. Scale 1:31,680. $1.25.

I-629. Geology, structure, and uranium deposits of the Cortez quadrangle, Colorado and Utah, compiled by D. D. Haynes, J. D. Vogel, and D. G. Wyant. 1972. Lat 37" to 38°, long 108" to 110". Scale 1:250,000. 2 sheets. $3.25 per set. (Reprinted 1977.)

I-634. Maps showing soil analyses of interest for prospecting the Montezuma stock, Summit County, Colo., by G. J. Neuerburg. 1971. Lat about 39" 35' to 39" 37'30", long about 105" 50' to 105" 55'. Scale 1:31,680. $1.25.

MISCELLANEOUS INVESTIGATIONS SERIES-Continued

I-687. Geologic map of the lower Cache La Poudre River basin, north-central Colorado, by L. A. Hershey and P. A. Schneider, Jr. 1972. Lat 40° 25' to 40° 50', long 104" 30' to 105" 10'. Scale 1:62,500. $1.50.

I-688. Generalized Tectonic map of North America, by P. B. King and G. J. Edmonston. 1972. Scale 1:15,000,000. $1.75.

I-697. Reconnaissance geologic map of the Cedaredge area, Delta County, Colo., by W. J. Hail, Jr. 1972. Lat 38" 45' to 39°, long 107" 45' to 108°. Scale 1:48,000. $1.75.

I-698. Reconnaissance geologic map of the Hotchkiss area, Delta and Montrose Counties, Colo., by W. J. Hail. Jr. 1972. Lat 38" 37'30" to 39°, long 107" 30' to 107" 45'. Scale 1:48,000. $1.75.

I-731. Generalized surficial geologic map of the Denver area, Colorado, by G. H. Chase and J. A. McConaghy. 1972 (1973). Lat 39" 22'30" to 40°, long 104" 37'30" to 105" 20'. Scale 1:62,500. $1.50.

I-736. Geologic and structure map of the Grand Junction quadrangle, Colorado and Utah, compiled by W. B. Cashion. 1973. Lat 39" to 40°, long 108" to 110°. Scale 1:250,000. $1.75.

I-750. Map showing geologic and structural control of ore deposits, Montezuma district, central Colorado, by G. J. Neuerburg and Theodore Botinelly. 1972 (1973). Lat 39" 30' to 39" 37'30", long 105" 47'30" to 105" 55'. Scale 1:31,680. $1.25.

I-761-A. Surticial and bedrock geologic map of the Golden quadrangle, Jefferson County, Colo., by Richard Van Horn. 1972. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.75. (Reprinted 1977.)

I-761-B. Map showing landslides in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-C. Map showing areas of potential rockfalls in the Golden quadrangle, Jefferson Countv, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30". long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-D. Map showing earth materials that may compact and cause settlement in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973 (1974). Lat 39" 45' to 39" 45' to 39" 52'30", long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.50.

I-761-E. Map showing man-modified land and man-made deposits in the Golden quadrangle, Jefferson County, Colo., by H. E. Simpson. 1973. Lat 39" 45' to 39" 52'30", long 105" 07'30" to 105" 15'. Scale 1:24,000. $1.25.

I-764. Geologic map of the Durango quadrangle, southwestern Colorado, compiled by T. A. Steven, P. W. Lipman, W. J. Hail, Jr., Fred Barker, and R. G. Luedke. 1974. Lat 37" to 38°, long 106" to 108". Scale 1:250,000. $1.75.

I-770-A. Geologic map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry and R. M. Lindvall. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.75.

I-770-B. Map showing areas of past flooding in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104°52'30". Scale 1:24,000. $1.25.

1-770-C. Map showing transportation routes in the Parker quadrangle, Arapahoe and Douglas Counties, Colo.. bv J. 0. Maberrv. 1972. Lat 39" 30' to 39" 37'30". long 104 45' to 104" 52'30". Scale 1:24,000. $1.50."

I-770-D. Map showing relative swelling-pressure potential of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-E. Map showing landslide-deposits and areas of potential landsliding in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-F. Slope map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30". lone 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-G. Map showing relative erodibility of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties. Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30", long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

I-770-H. Map showing relative excavatability of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39" 30' to 39" 37'30". long 104" 45' to 104" 52'30". Scale 1:24,000. $1.50.

1-770-I. Map showing inferred relative permeability of geologic materials in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52′30″, Scale 1:24,000. $1.50.

I-770-J. Map of deposits especially susceptible to compaction or subsidence, Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1972. Lat 39° 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-K. Map showing approximate ground-water conditions in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. O. Maberry and E. R. Hampton. 1972. Lat 39” 30’ to 39” 37′30″, long 104° 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

1-770-L. Map showing construction materials resources in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-M. Map of pioneer trails, stage stops, and areas with a view in the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-770-N. Vegetation map of the Parker quadrangle, Arapahoe and Douglas Counties, Colo., by J. R. Keith and J. 0. Maberry. 1973. Lat 39” 30’ to 39” 37′30″, long 104” 45’ to 104” 52’30”. Scale 1:24,000. $1.50.

I-785-A. Map showing areas of selected potential geologic hazards in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-B. Map showing ground-water potential in the Aspen quadrangle, Pitkir County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-C. Map showing relative ease of excavation in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-785-D. Map showing mines, prospects, and areas of significant silver, lead, and zinc production in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106° 52’30”. Scale 1:24,000. $1.25.

I-785-E. Slope map of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106° 52’30”. Scale 1:24,000. $1.50.

I-785-F. Map showing relative permeability of rocks and surficial deposits of the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’ 30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.25.

I-785-G. Map showing avalanche areas in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15’, lone 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.25.

I-785-H. Map showing typos of bedrock and surficial deposits in the Aspen quadrangle, Pitkin County, Colo., by Bruce Bryant. 1972. Lat 39” 07’30” to 39” 15′, long 106” 45’ to 106” 52’30”. Scale 1:24,000. $1.50.

I-786-A. Geologic map of the Evergreen quadrangle, Jefferson County, Colo., by D. M. Sheridan, J. C. Reed, Jr., and Bruce Bryant. 1972 (1973). Lat 39“ 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.75.

I-786-B. Vegetation map of the Evergreen quadrangle, Jefferson County, Colo., by J. C. Reed, Jr., and J. R. Keith. 1972. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

I-786-C. Slope map of the Evergreen quadrangle, Jefferson County, Colo., by P. W. Schmidt. 1972. Lat 39” 37’30” to 39” 45’, long 105” 15’ to 105” 22’30”. Scale 1:24.000. $1.50.

I-786-D. Map showing approximate density of houses in the Evergreen quadrangle, Jefferson County, Colo., by Bruce Bryant and J. C. Reed, Jr. 1972. Lat 39” 37’30” to 39 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

I-786-E. Map showing approximate locations, depths, and estimated yields of water wells in the Evergreen quadrangle, Jefferson County, Colo., by P. W. Schmidt and J. C. Reed, Jr. 1972 (1973). Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.25.

I-786-F. Map showing faults, joints, foliation, and surficial deposits in the Evergreen quadrangle, Jefferson County, Colo., by J. C. Reed, Jr., D. M. Sheridan, and Bruce Bryant. 1973. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.50.

MISCELLANEOUS INVESTIGATIONS SERIES-Continued

I-786-G. Map showing thermal lineaments in the Evergreen quadrangle, Jefferson County, Colo., by T. W. Offield and H. A. Pohn. 1975. Lat 39” 37’30” to 39” 45′, long 105” 15’ to 105” 22’30”. Scale 1:24,000. $1.25.

I-790-A. Geologic map of the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39° 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.75.

I-790-B. Map showing landslides and areas susceptible to landsliding in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

1-790-C. Map showing areas containing swelling clay in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105° 07′30″ to 105” 15’. Scale 1:24,000. $1.25.

I-790-D. Map showing potential source areas for non-metallic mineral resources. Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39° 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-790-E. Map showing some points of geologic interest in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-790-F. Map showing watercourses and areas inundated by historic floods in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972. Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

I-790-G. Map showing inferred relative permeability of geologic materials in the Morrison quadrangle, Jefferson County, Colo., by G. R. Scott. 1972 (1973). Lat 39” 37’30” to 39” 45′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.25.

I-791. Maps showing the approximate configuration and depth to the top of the Laramie-Fox Hills aquifer, Denver basin, Colorado, by J. C. Romero and E. R. Hampton. 1972. Lat about 38” 45’ to 40” 30′, long 104” to about 105”. Scale 1:500,000. $1.25.

I-792-A. Map showing rock fractures and veins in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1973. Lat 39” 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-792-B. Map showing density of dwelling units in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by H. R. Covington and D. J. Gable. 1973. Lat 39 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-792-C: Map showing water wells and springs in the Tungsten quadrangle, Boulder, Gilpin, and Jefferson Counties, Colo., by D. J. Gable. 1973. Lat 39” 52’30” to 40°, long 105” 22’30” to 105” 30’. Scale 1:24,000. $1.25.

I-828. Geologic map of the Platoro Caldera area, southeastern San Juan Mountains, southwestern Colorado, by P. W. Lipman. 1974 (1975). Lat 37” 15’ to 37” 30′, long 106 15’ to 106° 45’. Scale 1:48,000. $1.75.

I-830. Geologic map and sections of the Holy Cross quadrangle, Eagle, Lake Pitkin, and Summit Counties, Colo., by Ogden Tweto. 1974. Lat 39” 15’ to 39” 30′, long 106” 15’ to 106” 30’. Scale 1:24,000. 2 sheets. $3.50 per set.

I-833. Geologic map and cross sections of the La Veta Pass, La Veta, and Ritter Arroyo quadrangles, Huerfano and Costilla Counties, Colo., by J. D. Vine. 1974. Lat 37” 30’ to 37” 37′30″, long 104” 52’30” to 105” 15’. Scale 1:48,000. $1.50.

I-855-A. Lakes in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by J. F. Ficke and T. W. Danielson. 1973 (1974). Lat 40” to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-855-B. Land-use classification map of the Boulder-Fort CollinsGreeley area, Front Range Urban Corridor, Colorado, by L. B. Driscoll. 1974. Lat 40° to 40” 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-855-C. Map showing availability of hydrologic data, Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by E. R. Hampton G. A. Clark, and M. H. McNutt. 1974 (1975). Lat 40° to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-855-D. Map showing potential sources of gravel and crushed-rock aggregate, in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colo., by R. B. Colton and H. R. Fitch. 1974. Lat 40” to 40° 37′30″, long 104° 37’30” to 105° 22′30″. Scale 1:100,000. $1.75.

I-855-E. Map showing flood-prone areas, Boulder-Fort Collins—Greeley area, Front Range Urban Corridor, Colo., by J. F. McCain and W. R. Hotchkiss. 1975. Scale 1:100,000. $1.25.

MISCELLANEOUS INVESTIGATIONS SERIES-Continued

I-855-F. Map showing outstanding natural and historic landmarks in the Boulder-Fort Collins-Greeley area, Front Range Urban Corridor, Colorado, by B. N. Petrie. 1975. Lat 40” to 40° 37′30″, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-A. Map showing potential sources of gravel and crushed-rock aggregate in the greater Denver area, Front Range Urban Corridor, Colo., by D. E. Trimble and H. R. Fitch. 1974. Lat 39° 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-856-B. Lakes in the Greater Denver area, Front Range Urban Corridor, Colo., by T. W. Danielson. 1975. Lat 39” 22’30” to 40”. lone 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-C. Map showing availability of hydrologic data published by the U.S. Environmental Data Service, and by the U.S. Geological Survey and cooperating agencies, Greater Denver area, Front Range Urban Corridor, Colorado, by E. R. Hampton. 1975. Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-D. Map showing flood-prone areas, Greater Denver area, Front Range Urban Corridor. Colo.. by J. F. McCain and W. R. Hotchkiss. 1975. Lat 39” 22’30” to 40°, lona 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-E. Land-use classification of the Greater Denver area, Front Range Urban Corridor, Colo., by L. B. Driscoll. 1975 (1976). Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000. $1.75.

I-856-F. Map showing outstanding natural and historic landmarks in the greater Denver area, Front Ranee Urban Corridor. Colorado. by B. N. Petrie. 1976. Lat 39” 22’30” to 40°, long 104° 37′30″ to 105” 22’30”. Scale 1:100,000. $1.25.

I-856-G. Historic trail map of the Greater Denver area, Colorado, by G. R. Scott. 1976. Lat 39” 22’30” to 40°, long 104” 37’30” to 105” 22’30”. Scale 1:100,000 (1 inch = about 1.6 miles). Sheet 30 by 37 inches. $1.25.

I-857-A. Map showing potential sources of gravel and crushed-rock aggregate in the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colo., by D. E. Trimble and H. R. Fitch. 1974. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to 105”. Scale 1:100,000. $1.75.

I-857-B. Land-use classification map of the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colorado, by L. B. Driscoll. Lat 38” 37’30” to 39” 22’30”. long 104” 37’30” to 105” 07’30”. Scale 1:100,000. $1.75.

I-857-C. Map showing flood-prone areas, Colorado Springs—Castle Rock area, Front Range Urban Corridor, Colorado, by J. F. McCain and W. R. Hotchkiss. 1975. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to about 105”. Scale 1:100,000. $1.25.

I-857-D. Map showing availability of hydrologic data published as of 1974 by the U.S. Environmental Data Service and by the U.S. Geological Survey and cooperating agencies, Colorado Springs--Castle Rock area, Front Range Urban Corridor, Colorado, by L. 0. Anna. 1975. Lat 38” 37’30” to 39” 22′30″, long 104” 37’30” to about 105”. Scale 1:100,000. $1.25.

I-857-E. Lakes in the Colorado Springs-Castle Rock area, Front Range Urban Corridor, Colorado., by D. B. Adams. 1976. Lat 38” 37’30” to 39” 22’30”. lone: 104” 37’30” to 105” 07’30”. Scale 1:100,000. $1.50.

I-869. Reconnaissance geologic map of the Royal Gorge quadrangle, Fremont and Custer Counties.. Colo.. bv R. B. Tavlor. G. R. Scott. R. A. Wobus, and R. C. Epis. 1975. Lat 38’ 15’ to 38” 30′, long 105° 15’ to 105” 30′. Scale 1:62,500. $1.50.

I-870. Reconnaissance geologic map of the Deer Peak quadrangle and southern part of the Hardscrabble Mountain quadrangle, Custer and Huerfano Counties, Colo., by R. B. Taylor. 1974 (1975). Lat 38” to about 38” 09′, long 105” 07’30” to 105” 15’. Scale 1:24,000. $1.50.

I-892. Reconnaissance geologic map of the Howard quadrangle, central Colorado, by R. B. Taylor, G. R. Scott, and R. A. Wobus. 1975. Lat 38” 15’ to 38” 30′, long 105” 45’ to 106”. Scale 1:62,500. $1.50.

I-900. Reconnaissance geologic map of the Cotopaxi 15-minute quadrangle, Fremont and Custer Counties, Colo., by R. B. Taylor, G. R. Scott, R. A. Wobus, and R. C. Epis. 1975. Lat 38” 15’ to 38” 30′, long 105” 30’ to 105” 45’. Scale 1:62,500. $1.50.

I-901. Geologic map of the lower Conejos River Canyon area, southeastern San Juan Mountains, Colo., by P. W. Lipman. 1975. Lat 37” to 37” 15′, long 106” to 106” 30’. Scale 1:48,000. $1.50.

MISCELLANEOUS INVESTIGATIONS SERIES-Continued

I-912. Magnetic inclination in the United States-Epoch 1975.0, by N. W. Peddie, W. J. Jones, and E. B. Fabiano. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-913. Magnetic horizontal intensity in the United States-Epoch 1975.0, by E. B. Fabiano and W. J. Jones. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-914. Magnetic vertical intensity in the United States-Epoch 1975.0, by W. J. Jones and E. B. Fabiano. 1976 (1977). Two sheets. Scale 1:5,000,000 (1 inch = about 80 miles). Sheet 33 by 47 inches. $3.

I-915. Magnetic total intensity in the United States-Epoch 1975.0, by E. B. Fabiano, N. W. Peddie, and W. J. Jones. 1976. 2 sheets. Scale 1:5,000,000. $3.

I-930. Historic trail maps of the Pueblo 1" x 2" quadrangle, Colorado, by G. R. Scott. 1975 (1976). Lat 38" to 39°, long 104" to 106". Scale 1:250,000. Accompanied by 9-page text. 2 sheets. $2.50 per set.

I-937. Geologic and biostratigraphic map of the Pierre Shale in the Canon City-Florence basin and the Twelvemile Park area, south-central Colorado, by G. R. Scott and W. A. Cobban. 1975 (1976). Lat 38" 12'30" to 38" 30', long 105" to 105" 15'. Scale 1:48,000. $1.25.

I-944. Geologic map of the Lamar quadrangle, COLORADO, and KANSAS, by J. A. Sharps. 1976. Lat 38" to 39", long 102" to 104". Scale 1:250,000 (1 inch = about 4 miles). Structure-contour interval 100 feet (30.5 m). Sheet 25% by 40 inches. $1.50.

I-952. Geologic map of the Del Norte area, eastern San Juan Mountains, Colorado, by P. W. Lipman. 1976. Lat 37" 30' to 37" 52'30", long 106" 07'30" to 106" 30'. Scale 1:48,000. $1.50.

I-962. Geologic map of the Lake City caldera area, western San Juan Mountains, southwestern Colorado, by P. W. Lipman. 1976 (1977). Lat 37" 45' to 38" 07'30", long 107" 15' to 107" 37'30". Scale 1:48,000 (1 inch = 4,000 feet). Sheet 39 by 58 inches. $1.50.

I-964. Preliminary map of landslide deposits in Colorado, by R. B. Colton, J. A. Holligan, L. W. Anderson, and P. E. Patterson. 1976. Lat 37" to 41". long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 40 by 52 inches: $1.25.

I-965. Map showing nonmetallic mineral resources (except fuels) in bedrock, Front Range Urban Corridor. Colorado, by E. J. Crosby. 1976 (1977). Two sheets. Lat 38" 37'30" to 40° 37'30", long 104" 37'30" to 105" 22'30". Scale 1:100,000 (1 inch = about 1.6 miles). Sheet 1, 34 by 44 inches; sheet 2, 39 by 48 inches. $3 per set.

I-966. Geologic map of the South Fork area, eastern San Juan Mountains, southwestern Colorado, by P. W. Lipman and T. A. Steven. 1976. Lat 37" 30' to 37" 45', long 106 30' to 106° 45'. Scale 1:48,000 (1 inch = 4,000 feet). Sheet 28 by 30 inches. $1.50.

I-972. Geologic map of the Craig 1" by 2" quadrangle, northwestern Colorado, compiled by Ogden Tweto. 1976. Lat 40" to 41°, long 106" to 108". Scale 1:250,000 (1 inch = about 4 miles). Sheet 29 by 41 inches. $1.50.

I-973-A. Map showing types of bedrock and surficial deposits in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke and W. S. Burbank. 1976 (1977). Lat 37" 52'30" to 38°, long 107" 45' to 107" 52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 28 by 28 inches. $1.50.

I-973-B. Map showing potential geologic hazards in the Telluride quadrangle, San Miguel, Ouray, and San Juan Counties, Colorado, by R. G. Luedke and W. S. Burbank. 1977. Lat 37" 52'30" to 38°, long 107" 45' to 107" 52'30". Scale 1:24,000 (1 inch = 2,000 feet). Sheet 29 by 30 inches. $1.50.

I-980. Engineering geologic map of the Indian Hills quadrangle, Jefferson County, Colorado, by R. D. Miller and Bruce Bryant. 1976 (1977). Lat 39" 30' to 39" 37'30", long 105" 07'30" to 105" 15'. Scale 1:24,000 (1 inch = 2,000 feet). Sheet 37 by 39 inches. $1.50.

I-1039. Energy resources map of Colorado, by U. S. Geological Survey and Colorado Geological Survey. 1977. Lat 37' to 41°, long 102" to 109". Scale 1:500,000 (1 inch = about 8 miles). Sheet 42 by 59 inches. $1.75.

MISSOURI BASIN STUDIES

1. Mineral resources of the Missouri Valley region, compiled by D. H. Dow, D. M. Larrabee, and S. E. Glabaugh. 1945-46. These maps cover the entire basin. They show the sedimentary and igneous rocks of different ages. Structure-contour lines are also given. Part 1 shows the metallic mineral resources, part 2, the nonmetallic mineral resources, part 3, fuel resources, and part 4, construction materials. Scale 1:2,500,000.

MISSOURI BASIN STUDIES-Continued

*2. Preliminary map showing sand and gravel deposits of Colorado, compiled by Helen Varnes and D. M. Larrabee. 1946. Scale 1:500,000.

*8. Map showing mineral deposits of Colorado, compiled by R. P. Fischer, Wilbur Burbank, Helen Cannon, and others. 1946. Scale 1:1,000,000.

*10. Map showing construction materials and nonmetallic mineral resources of Colorado, compiled by D. M. Larrabee, S. E. Clabaugh, W. R. Griffitts, and others. 1947. Scale 1:500,000.

*MOSQUITO RANGE, COLO. Preliminary geologic map of west slope of Mosquito Range near Leadville, Colo. Geology, by G. H. Behre, Jr., assisted by E. N. Goddard, and A. E. Sandburg. 1939. Scale 1:12,000.

OIL AND GAS INVESTIGATIONS CHARTS

*7. Correlation of basal Permian and older rocks in southwestern Colorado, northwestern New Mexico, northeastern Arizona, and southeastern Utah, by N. W. Bass. 1945.

16. Mesozoic and Paleozoic stratigraphy in northwestern Colorado and northeastern Utah, by C. R. Thomas, F. T. McCann, and N. D. Ramon. 1945.2 sheets. $2.50 per set.

*39. Pre-Pennsylvanian rocks along the Front Range of Colorado, by J. C. Maher. 1950.

*OC-42. Subsurface geologic cross sections of Mesozoic rocks in northeastern Colorado, by R. W. Blair. 1951. 2 sheets.

OC-46. Correlation of Permian and Pennsylvanian rocks from western Kansas to the Front Range of Colorado, by J. C. Maher and J. B. Collins. 1952. 3 sheets. $3.75 per set.

OC-59. Stratigraphy of Paleozoic rocks in northwestern Colorado, by W. D. Hallgarth. 1959 (1960). $1.25.

OC-60. Stratigraphy of the Dakota group along the northern Front Range foothills, Colorado, by K. M. Waage. 1959. $1.25.

OC-63. Block diagram of the San Rafael Group and underlying strata in Utah and part of Colorado, by J. C. Wright and D. D. Dickey. 1963. $1.25.

OC-65. Chart showing correlation of selected key units in the organic-rich sequence of the Green River Formation, Piceance Creek basin, Colorado, and Uinta Basin, Utah, by W. B. Cashion and J. R. Donnell. 1972. $1.25:

OC-67. Chart showing correlation of selected restored stratigraphic diagram units of the Eocene Uinta and Green River Formations, east-central Piceance Creek basin, northwestern Colorado, by R. B. O'Sullivan. 1974. $1.25.

OC-68. Stratigraphic sections across Upper Cretaceous Mancos Shale-Mesaverde Group boundary, eastern Utah and western Colorado, by J. R. Gill and W. J. Hail, Jr. 1975. $1.25.

OC-69. Stratigraphic sections of some Triassic and Jurassic rocks from Douglas, Wyoming to Boulder, Colorado, by G. N. Pipiringos and R. B. O'Sullivan. 1976. $1.25.

OIL AND GAS INVESTIGATIONS MAPS

*7. Structure contour map of the exposed rocks in the Rangely anticline, Rio Blanco and Moffat Counties, Colo., by C. R. Thomas and others. 1944. Scale 1:31,680. (Superseded in part by Map 67.)

10. Map showing thickness and general character of the Cretaceous deposits in the western interior of the United States. bv J. B. Reeside, Jr. 1944. Scale 1:13,939,200. $1.25.

32. Geology of the Washakie Basin: Sweetwater and Carbon Counties, Wyo., and Moffat County, Colo., by W. H. Bradley. 1945. Scale 1:190,080. $1.25.

*41. Structure contour mans of the Raneely anticline, Rio Blanco and Moffat Counties, Colo., by C. R. Thomas and others. 1945. Scale 1:31,680. (Superseded by Map 67.)

*67. Subsurface maps of the Rangely anticline, Rio Blanco County, Colo., by N. W. Bass. 1948. Scale 1:31,680.

*68. Structure contour map of the surface rocks of the Model anticline, Las Animas County, Colo., by N. W. Bass. 1947. Scale 1:42,240.

*73. Map of Colorado showing dry holes and oil and gas fields, by F. K. Demok, H. R. Castor, and N. W. Bass. 1947. Scale 1:500,000. (Superseded by Map OM-116.)

*81. Geology of the southern part of Archuleta County, Colo., by G. H. Wood, V. C. Kelley, and A. J. MacAlphin. 1948. Scale 1:63,360.

*93. Geology of the Eguar-Gypsum Valley area, San Miguel and Montrose Counties, Colo., by W. L. Stokes and D. A. Phoenix. 1948. Scale 1:48,000.

94. Geology of Naval Oil Shale Reserves 1 and 3, Garfield County, Colo., by D. C. Duncan and N. M. Denson. 1949. Scale 1:31,680. 2 sheets. $2.50 per set.

OIL AND GAS INVESTIGATIONS MAPS-Continued

*96. Stratigraphy and geologic structure in the Piedra River Canyon, Archuleta County, Colo., by C. B. Read, G. H. Wood, A. A. Wanek, and Pedro Verastegui Mackee. 1949. Scale 1:48,000.

*101. Pre-Pennsylvanian geology of southwestern Kansas, southeastern Colorado, and the Oklahoma Panhandle, by J. C. Maher and J. B. Collins. 1949. Scale 1:1,013,760. 4 sheets.

109. Geology and coal resources of the Durango area, La Plata and Montezuma Counties, Colo., by A. D. Zapp. 1949. Scale 1:31,680. 2 sheets. $2.50. per set.

*OM-114. Geology of DeBeque oil-shale area, Garfield and Mesa Counties, Colo., by F. R. Waldron, J. R. Donnell, and J. C. Wright. 1951. Scale 1:62,500. 2 sheets.

*OM-116. Map of Colorado showing test wells for oil and gas, pipelines, oil, and gas fields, and areas of pre-Cambrian rocks, compiled by F. W. Walker and N. W. Bass. 1951. Scale 1500,000. 2 sheets.

OM-119. Geology and oil-shale resources of the eastern part of the Piceance Creek Basin, Rio Blanco and Garfield Counties, Colo., by D. C. Duncan and Carl Belser. 1950. Scale 1:96,000. $1.25.

OM-120. Geology of Dove Creek area, Dolores and Montezuma Counties, Colo., by E. A. Finley. 1951. Scale 1:48,000. $1.25.

*OM-134. Geology of the Cathedral Bluffs oil-shale area, Rio Blanco and Garfield Counties, Colo., by J. R. Donnell, W. B. Cashion, and J. H. Brown, Jr. 1953. Scale 1:62,500. (See Bulletin 1082-L.)

*OM-135. Permian and Pennsylvanian rocks of southeastern Colorado and adjacent areas, by J. C. Maher and J. B. Collins. 1953. Scale 1:1,143,180.

*OM-138. Geology of the Ignacio area, Ignacio and Pagosa Springs quadrangles, La Plata and Archuleta Counties, Colo., by Harley Barnes. 1953. Lat 37” 15’ to 37” 20′, long 107” 20’ to 107” 40’. Scale 1:63,360. 50¢.

*OM-146. Geology of the La Veta area, Huerfano County, by R. B. Johnson and J. G. Stephens. 1954. Lat 37” 30’30” to 37” 45′, long 104” 55’ to 105” 07’30”. Scale 1:31,680.

OM-149. Geology and fuel resources of the Red Mesa area, La Plata and Montezuma Counties, Colo., by Harley Barnes, E. H. Baltz, Jr., and P. T. Hayes. 1954. Lat 37” to 37” 20′, long 107” 52’30” to 108° 20’. Scale 1:62,500. $1.25.

*OM-152. Geologic map of the Mesa Verde area, Montezuma County, Colo., by A. A. Wanek. 1954. Lat 37” to 37” 20′, long 108” 20’ to 108” 45’. Scale 1:63,360. (See Bulletin 1072-M.)

OM-153. Geology of the Bonanza-Dragon oil-shale area, Uintah County, Utah, and Rio Blanco County, Colo., by W. B. Cashion and J. H. Brown, Jr. 1956. Scale 1:62,500. 2 sheets. $2.50 per set.

OM-161. Geologic map of the Walsenburg area, Huerfano County, Colo., by R. B. Johnson and J. G. Stephens. 1955. Scale 1:31,680. $1.25. (See Bulletin 1042-o.)

OM-174. Geology of the Trinidad-Aguilar area, Las Animas and Huerfano Counties, Colo., by R. L. Harbour and G. H. Dixon. 1956. Lat 37” 10’ to 37” 30′, long 104” 30’ to 104” 45’. Scale 1:31,680. $1.50. (See Bulletin 1072-G.)

OM-176. Preliminary structure contour map of the Colorado plains, by E. A. Finley, C. E. Dobbin, and E. E. Richardson. 1955 (1956). Lat 37” to 41°, long 102” to 105”. Scale 1500,000. $1.25.

OM-183. Preliminary geologic map of the northern part of the Raton Mesa region and Huerfano Park in parts of Las Animas, Huerfano and Custer Counties, Colo., by R. B. Johnson, G. H. Wood, Jr., and R. L. Harbour. 1958. Lat 37” 30’ to 37” 52′30″, long 104” 37’30” to 105” 22’30”. Scale 1:63,360. 2 sheets, $3 per set. (See Bulletin 1071-D.)

OM-184. Index map of central midcontinent region giving lines of sections that show detailed lithology of Paleozoic and Mesozoic rocks, by Jeannette Fox and M. G. Sheldon. 1957. Lat 33” to 46°, long 89” to 106°. Scale 1:2,500,000. $1.50.

GM-209. Preliminary structure contour map on top of salt in the Paradox member of the Hermosa Formation in the salt anticline region, Colorado and Utah, by D. P. Elston and E. M. Shoemaker. 1961. Lat 37” 45’ to 39°, long 108” to 110”. Scale 1:250,000. $1.25.

OM-216. Geologic map of the Thornburg oil and gas field and vicinity, Moffat and Rio Blanco Counties, Colo., by J. R. Dyni. 1966. Area lies in the vicinity of lat 40°15′, long 107° 40’. Scale 1:24,000. Accompanied by 7-page text. $1.25.

*PALEOCENE DEPOSITS OF THE ROCKY MOUNTAINS AND PLAINS, by R. W. Brown. 1949. Shows the areas of outcrop of the earliest Tertiary (Paleocene) rocks from Montana and North Dakota south to Arizona and New Mexico. The upper and lower boundaries of the Paleocene deposits and their area1 relations with Cretnceous and younger Tertiary rocks are indicated. A brief discussion of Paleocene formations is printed on the same sheet. Scale 1:1,000,000. (See Professional Paper 375.)

PIKES PEAK AND VICINITY, COLORADO. 1948-56 (1957). Text on the reverse side of the map discusses the geologic story of Pikes Peak and the surrounding region, by A. H. Koschmann. Available in contour or shaded relief editions. $1 each.

MISCELLANEOUS REPORTS (free upon application to the Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202):

List 1. Press releases, preliminary maps, and preliminary reports released between Jan., 1, 1938, and Jan. 1. 1945.

List 2. Press releases, preliminary maps, and preliminary reports released between Jan. 1, 1945, and Jan. 1. 1946.

REFERENCE LIBRARIES

Many of the publications listed herein may be consulted in the following libraries in Colorado:

ALAMOSA:
  Adams State College.
BOULDER:
  University of Colorado.
COLORADO SPRINGS:
  Colorado College.
DENVER
  Colorado Geological Survey.
  Colorado State.
  Colorado Water Conservation Board.
  Div. of Water Resources.
  Jefferson County Public.
  Public.
  Regis College.
  State Bureau of Mines.
  U.S. Geological Survey Offices-
    Denver Federal Center and
    Rm. 1012, Federal Bldg.
  University of Denver.
FORT COLLINS:
  Colorado State University.
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